SOME DETERMINANTS OF COMMERCIAL BANK BEHAVIOR

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The central theme of this dissertation is commercial bank behavior. Following the introduction in Chapter 1, Chapter 2 examines U.S. banks' choices of foreign activities. Chapter 3 analyzes Hungarian commercial banks' branch network and interest rate choices. Specifically, Chapter 2 relies on a theoretical model and estimation to examine how banks' scope of operations and size, and various host market characteristics, determine banks' choices of foreign market entry/exit, and foreign loan/deposit quantities. Applying the Bajari, Benkard, and Levin (2007) two–step estimation method, the determinants of the optimal foreign loan and deposit choices are estimated in the first stage. The results (1) confirm the presence of and correct for significant selection bias arising from the correlation in banks' entry and loan volume choices; (2) show different sensitivities of cross–border and affiliate loans to market and bank traits, and (3) characterize the role of bank scope in bank behavior. In the second stage, forward simulation is used to estimate banks' and regulators' risk aversion parameters, the fixed foreign market entry costs and scrap (liquidation) values. Results show that entry costs are higher in inefficient and profitable markets with greater entry barriers and stronger government presence in banking. Scrap values move together with entry costs, and regulators are more risk averse than banks. Regulatory risk aversion is greater in inefficient markets with stricter regulations and lower enforcement power. The chapter concludes with simulation exercises that describe the strong discouraging impact of regulations on U.S. banks'

foreign participation.

Chapter 3 examines the dynamic behavior of imperfectly competitive Hungarian banks. The chapter consists of a theoretical model and empirical analysis. A simulation–based estimation method is applied to bank–level data to estimate the impact of bank and market traits on optimal interest rate and branch network expansion choices. Estimation results confirm the importance of branch network competition. Furthermore, branch setup cost and scrap value estimates are high, and strongly positively correlated with each other and with relevant producer price indices. Chapter 3 concludes with various simulation exercises, finding a strong impact of competitors' branch network size on bank behavior.

BIOGRAPHICAL SKETCH

Judit Temesvary was born and raised in Szentes, Hungary. After getting her high school diploma in Szentes, she moved to the United States to attend Wells College in Aurora, New York. She earned her Bachelor of Arts degree from Wells College in May 2004. Judit began her graduate studies in the Economics Ph.D. program at Cornell University in the Fall of 2004. Prior to the completion of her Ph.D. work, Judit obtained a Master of Arts in Economics degree from Cornell in May 2009. Judit is starting as an Assistant Professor of Economics at Hamilton College in the Fall of 2011.

To My Mother Erzsébet and My Friend Tom

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CHAPTER 1
INTRODUCTION

The central theme of this dissertation is commercial bank behavior. Understanding the determinants of commercial banks' behavior — more specifically, their decisions regarding lending, deposit–taking and branch-networking — is crucial from both national and international perspectives. At the national level, decisions of banks regarding the quality and quantity of their services are important for consumer welfare as well as for effective bank regulation. At the international level, the types and magnitudes of cross–country commercial bank activities have significant implications for the development prospects of the generally less prosperous host country, as well as macroeconomic consequences for the source country. In light of the importance of commercial banking, the purpose of this dissertation is to analyze how banks make their choices. Chapter 2 examines how U.S. banks make decisions about their foreign operations. Chapter 3 studies the competitive behavior of Hungarian commercial banks.

There are numerous empirical studies of bank behavior within particular national markets, and some studies of the determinants of international cross–border lending. However, there are several unexamined issues relating to the role of imperfect competition, the importance of entry barriers as deterrents of market expansion and regulations. The study of these issues makes this dissertation a contribution. By studying the international activities of U.S. banks, Chapter 2 of this dissertation contributes by using a dynamic framework for (1) getting estimates of the entry costs and scrap values, as well as the stringency of the regulatory environment that banks consider in their decision to expand into new markets; (2) taking account of the role of imperfect competition in banks' location choices; (3) simultaneously examining the determinants of banks' market choices as well as their lending decisions; (4) addressing how banks' scope (a measure of the rate at which banks can trade return for risk) affects portfolio decisions in a context where returns are correlated across markets, and (5) examining the impact of bank and regulatory risk aversion changes on bank behavior. Looking at branch network competition in the Hungarian banking context, Chapter 3 contributes by using a dynamic framework to (a) get estimates of the branch setup costs and scrap values that banks consider in their choices of branch network size; (b) take account of branch network size as a strategic tool of monopolistically competitive commercial banks; (c) simultaneously examine banks' choices of interest rates and branch network size, and (d) analyze how competition in branch networks impacts bank profitability and behavior.

1.1 U.S. Commercial Banking on a Global Scale

Chapter 2 focuses on the determinants of the international activities of the largest U.S. commercial banks. The chapter provides a dynamic estimation of U.S. banks' foreign market entry/exit decisions, as well as their foreign loan and deposit choices. The analysis addresses how banks' scope of operations (measured by the lagged Sharpe ratio) and size (measured by total assets), together with various host market characteristics, determine banks' optimal choices of two types: which foreign markets to enter/exit, and the foreign loan/deposit volumes. These workings of determinants are studied with a dynamic model of foreign bank activity, where mean–variance utility maximizing banks can reach foreign markets both via cross–border loans (originating from the U.S.), and through foreign affiliate operations (after paying the setup costs).

Forward simulation using the Bajari, Benkard, and Levin (2007) two–step estimation method is applied to estimate the model on a panel data set constructed from 46 countries' market traits and the Federal Financial Institution Examination Council (1997-2005)'s Country Exposure Survey quarterly U.S. bank activities data. In the first stage of the estimation, maximum likelihood methods with the Heckman selection correction are used to analyze the determinants of the optimal foreign loan and deposit choices, and banks's choices of foreign market entry/exit. The first stage results confirm the importance of correcting for the selection bias in quantity choices emanating from foreign market entry/exit decisions. Furthermore, in both the entry/exit choice and the loan/deposit quantity choice estimates, bank scope (measured via the lagged Sharpe ratio) has over three times as great an impact as bank size (measured by total assets). There are also great differences in the sensitivities of cross-border and affiliate loans to bank and market traits.

Fixed setup costs and scrap (liquidation) values for a sample of foreign countries U.S. banks invest in are estimated in the second stage. In order to obtain estimates of the truly fixed costs that do not depend on banks' planned scale of operations, branch network costs and other scale–dependent operating costs are controlled for. The estimation results suggest that foreign markets with greater entry costs also have higher scrap values. Furthermore, the estimates are greater in foreign markets that are less efficient and competitive, more profitable and have greater government presence. In addition, bank regulators tend to be more risk averse in inefficient markets with stricter regulations and low prompt regulatory corrective power.

Simulation exercises with the estimated structural parameters are used to analyze the impact on U.S. banks' foreign activities of (1) raising bank risk aversion; (2) increases in the risk aversion of foreign country bank regulators, and (3) more risk averse U.S. bank regulators. The results suggest that greater bank and U.S. regulatory risk aversions reduce the value of U.S. banks' operations, and discourage bank activity. Greater bank and U.S. regulatory risk aversions divert U.S. bank assets abroad. On the other hand, more risk averse foreign regulators reduce the share of foreign assets, and within that, the share of affiliate loans relative to cross-border loans in banks' portfolio. These results are relevant for bank regulatory policy considerations. Overall, Chapter 2 contributes by formulating a dynamic estimation of U.S. commercial banks' optimal behavior in a global setting.

1.2 Hungarian Banks and Branch Networks

Chapter 3 of this dissertation focuses on the Hungarian commercial banking market. More specifically, the chapter examines the dynamic behavior of imperfectly competitive Hungarian banks. Understanding how Hungarian commercial banks make their choices on interest rates and branch networks is important for the policy–makers of a country where banks enjoy a large degree of market power. Chapter 3 presents a model where banks make interest rate and dynamic branch network expansion choices in imperfectly competitive markets. In the Salop–style spatial competition model, monopolistically competitive banks make simultaneous static interest rate and dynamic branch network size decisions to attract retail clients. In the corporate market, banks choose their interest rates according to perfect competition. A Markov perfect equilibrium that characterizes banks' optimal behavior over time is described.

After characterizing the optimal behavior of banks, Chapter 3 estimates the model using bank–level regulatory data on five large commercial banks operating in Hungary. A version of the Bajari, Benkard, and Levin (2007) method is applied to the panel data set to estimate banks' dynamic choices. The data set covers the period between January 2004 and November 2007. The first stage of this method yields estimates of the optimal interest rate and branch network choices as functions of bank and market traits. The detailed data set makes possible the estimation of interest rate choices by loan and currency type. The choices of branch network expansion/contraction are estimated with an ordered probit formulation. The policy function estimation results strongly confirm the importance of branch network competition, and its impact on banks' interest rate choices. Accordingly, banks are more likely to add new branches, and offer lower lending and higher deposit rates if competitors operate with bigger branch networks. Furthermore, banks with more branches charge higher lending rates and offer lower deposit rates.

The second stage estimation uses the predicted interest rates and branch network sizes to estimate the fixed setup costs and scrap values of branch network expansion. The estimated per–bank setup cost (with an average of 150 million HUF, or nearly 0.75 million USD) is 2.48 times greater than the mean scrap value (with an average of 110 million HUF, or approximately 0.55 million USD). These values are high by Hungarian measure, but still much lower than the survey estimates of 1 to 2 million USD presented in the previous literature for U.S. commercial banks. Setup costs and scrap values are strongly positively correlated, and move closely with indices of construction costs. Simulation exercises examine the impact of various parameters on banks' optimal behavior. Specifically, the impact of exogenous increases in fixed setup costs on branch network size and net interest income is examined, as well as the impact of increases in per capita consumer income and competitors' branch network size over time. These simulations confirm the importance of setup costs and branch network competition in bank behavior. The results presented in Chapter 3 can have important policy implications from the perspective of Hungarian bank regulators.

This dissertation gives insight into the determinants of the lending and location choices of monopolistically competitive commercial banks in the presence of diverse activities in imperfectly correlated markets. The results of Chapter 2 of this dissertation provide a more detailed view of U.S. banks' global activities. This has welfare as well as regulatory implications. The results in Chapter 3 underline the importance of accounting for branch networks in addition to interest rates as channels of intra-national bank competition. This too is relevant to forming effective regulations.

CHAPTER 2

THE DETERMINANTS OF U.S. BANKS' INTERNATIONAL ACTIVITIES

2.1 Introduction

Understanding the determinants of U.S. commercial banks' international activities is important from the perspectives of both the host countries and banks' countries of origin. The types and magnitudes of cross–country commercial bank activities have significant implications for the development prospects of the generally less prosperous host countries, as well as macroeconomic consequences for the source countries. Foreign banks are often beneficial for the host economies (Focarelli and Pozzolo, 2005; Goldberg, 2007). The benefits are most felt in the host financial sectors, as foreign banks help to improve the efficiency of host country banks (Bayraktar and Wang, 2005; Claessens, Demirguc-Kunt, and Huizinga, 2000, 2001; Claessens and Lee, 2002). Since financial sector development promotes economic growth, foreign bank entry is likely to be welfare enhancing (Bayraktar and Wang, 2006). In addition to the development benefits, foreign banks also promote host country financial stability. On one hand, the presence of foreign banks reduces the probability of banking crises (Asli Demirguc-Kunt, Levine, and Min, 1998; Levine, 1999). On the other hand, foreign banks are less sensitive to host market fluctuations, and therefore provide a buffer against financial shocks (Goldberg, 2007).

The internationalization of commercial banking has important consequences from the perspective of the generally more developed source countries as well. On one hand, domestic banks' foreign activities open a potential channel for the transmission of outside financial shocks. On the other hand, the increasingly foreign focus of banks can have significant consequences for the availability of domestic credit. In fact, the outflow of financial resources from domestic credit markets has increased to unprecedented levels during the past two decades. Looking at the United States, foreign assets of U.S. banks amounted to 900 billion USD by 2002, constituting about 18 percent of total U.S. bank assets and approximately 10 percent of total global bank lending. The foreign exposure of U.S. banks has declined in the past decade, mostly due to banks building up their domestic capital in response to stricter domestic capital rules (Ruud, 2002).

This paper examines the determinants of the international commercial banking activities of the largest U.S. banks. A thorough understanding of these operations is greatly complicated by the fact that there are various channels through which U.S. banks can participate in foreign markets — all with different macroeconomic consequences. In addition to domestic operations, U.S. banks can lend to foreign markets via cross–border loans, originating directly from the U.S. They can also participate in foreign retail loan and deposit markets by building foreign affiliates after paying the setup costs. This paper develops a modeling and dynamic estimation framework to examine how bank size, bank scope and host market traits (such as expected returns, costs and regulations) affect banks' choice of these foreign activities.

In a dynamic framework of foreign market entry and exit, greater bank size (total assets) encourages broader foreign operations by providing more resources for banks to incur the setup costs of foreign market entry. While previous literature has taken bank size as the sole measure of bank heterogeneity, this study is unique in that it examines the additional role of bank scope in banks' international activities. The lagged Sharpe ratio on banks' global portfolio measures bank scope. In a context where returns across markets are correlated, using the Sharpe ratio as the scope measure allows for the capture of the risk–return tradeoff improvement that results from entering new markets. Beyond size and scope, the impacts of market–specific capital and liquidity regulations, and proportional costs and taxes are also studied in this chapter. In particular, the question of interest is how these determinants contribute to two types of bank portfolio decisions: (1) the choice of which foreign markets to participate in (entry/exit decision), and (2) banks' choices of the volumes of cross–border loans, affiliate loans and deposits in these host markets (quantity choices).

This chapter moves beyond the existing literature by presenting a theoretical model, a contribution towards building the theoretical micro–foundations of a so–far purely empirical literature. This contribution takes the form of a monopolistic competition model where mean–variance utility maximizing banks make foreign market entry/exit decisions, and cross–border loan, foreign affiliate loan and deposit choices given their existing size, scope and the host market traits. Banks' goal is to weigh expected returns against portfolio risk in a dynamic framework where entry/exit choices have long-term consequences. The model focuses on interest rate (or market) risk as the only source of portfolio risk. Markets are subject to macro shocks in each country. Portfolio risk originates from the variance caused by fluctuations of the random country-specific interest rates which are globally correlated. However, macro–shocks move together across borders — therefore, banks can also rely on potentially variance–reducing correlations. Overall, banks' goal is to find the optimal risk-return tradeoff on their global portfolio subject to financing and regulatory constraints in each country.

This chapter also contributes by formulating a dynamic framework for estimating the presented theoretical model. Foreign banking is characterized by imperfect competition and frequent market entry/exit, which necessitate the incorporation of dynamics into the analysis. However, previous papers used static econometric methods, which have only very limited ability to address the issues at hand. Furthermore, such static methods do not allow for the analysis of the multi–period effects that policy changes have. The estimation method used in this chapter is due to Bajari, Benkard, and Levin (2007). The dynamic estimation method is applied to a panel data set constructed from 46 host countries' market characteristics and the Federal Financial Institution Examination Council's Country Exposure Survey quarterly U.S. bank activities data between 1997 and 2005.

In the first stage of the two–step dynamic estimation method, foreign market entry/exit probabilities and loan/deposit quantity choices are estimated as functions of bank size, bank scope and foreign market traits in each period separately. This first stage is equivalent to getting estimates of the policy functions based on all the state variables. Furthermore, this first stage allows for the estimation of transition probabilities for the endogenous states (such as foreign presence), as well as the exogenous states (such as bank size). The second stage of the estimation then uses these first–stage estimates to simulate bank's optimal discounted sum of utilities forward. The second stage is based on two pillars: the simulation of the values of many alternate paths of action, and the assertion that banks' observed actions reflect optimal choices. The second step consists of getting estimates of structural parameters that ensure the optimality of banks' observed actions compared to alternate policy paths. The structural parameters of interest are banks' and regulators' risk aversion parameters, the country specific entry costs, as well as the scrap values.

The estimation method is novel in that it examines the determinants of the major types of banks' foreign portfolio choices — the entry/exit decision, as well as the cross–border loan, affiliate loan and deposit quantity choices — simultaneously. This is new in the related literature, since so far there have only been papers (1) examining the type of foreign market participation, treating cross–border loans and foreign affiliates as the two dichotomous alternatives; and (2) focusing exclusively on the quantities of foreign loans, and their determinants.

First stage estimates of banks' entry/exit and loan/deposit quantity choices show that it is very important to examine these two types of decisions simultaneously. Banks' decisions of market entry/exit are strongly positively correlated with their choices of loan and deposit volumes – therefore they cannot be examined in isolation. The Heckman selection correction method in fact yields a correlation coefficient of 0.31 between the unobservable terms in the market entry and volume choices. Such strong correlation has major implications for the estimation of the policy functions. For instance, previous literature — which did not control for the role of entry barriers — found that bank size has a strong positive impact on the quantity of foreign affiliate loans banks make. However, controlling for market selection shows that bank size affects foreign lending significantly through the market entry decision as well — large banks are much more likely to acquire affiliates. The impact of bank size on the choice of affiliate volumes, conditional on market entry, is much smaller. The strong correlation of the market presence and loan/deposit quantity equations also indicates the important role of unobserved entry costs in the allocation of foreign activities — an issue that the second stage of the estimation addresses.

Furthermore, the first stage estimates prove that looking at the various types of foreign activities (cross–border loans, affiliate loans and deposits) one by one in a unified framework is important. The results below show that bank regulations, costs and returns have very different effects on cross–border loans, affiliate loans and deposits. These differences — which would be missed by grouping all types of foreign bank loans into one category — can have important policy consequences. Finally, the policy function estimates show that bank scope (captured by the Sharpe ratio) has significant explanatory power, in addition to the well–studied role of bank size. The results indicate that the scope effect is on average over three times as large as the effect of bank size.

The second step of the estimation relies on using the first–step policy function estimates to forward–simulate banks' optimal discounted sum of expected utility. Structural parameter estimates are obtained so as to ensure the optimality of the observed path of actions in comparison to alternate sub-optimal paths. In particular, this method yields estimates of banks' and regulators' risk aversion parameters, as well as the fixed entry costs and scrap values. The estimation controls for total operating (variable) costs (including costs proportional to branch network size). This is important to ensure that the estimates are truly reflective of the fixed entry costs and scrap values only. Accordingly, the cost estimates are moderate with a mean of 1.12 for entry costs and 0.56 for scrap values across countries. The entry cost estimates appear significantly higher in markets that are inefficient, profitable and have a strong government presence in banking. Scrap value estimates move closely together with entry costs. The second stage of the estimation also yields bank and regulatory risk aversion estimates. Getting an estimate of the bank risk aversion parameter is very important in the mean–variance framework, as it determine the rate at which banks trade risk for return, and hence the role of scope. The estimated bank risk aversion is 0.34, slightly higher than estimates in previous papers. There is great variation in regulatory risk aversion parameters across foreign markets — which are generally higher than bank risk aversion with a cross–country average of 0.52. Regulatory risk aversion appears higher in inefficient markets with a stricter bank–regulatory environment, which nonetheless have low enforcement power.

The chapter proceeds as follows. Section 2.2 provides motivation for the theoretical model's formulation in the context of related literature. Section 2.3 presents the model and characterizes the optimal foreign portfolio choices (entry/exit as well as loan/deposit quantities) as a Markov perfect equilibrium. Section 2.4 describes the econometric and simulation methods used for the estimation, and discusses the data. Section 2.5 presents the estimation results. Section 2.6 consists of simulation exercises. Section 2.7 concludes.

2.2 Motivation and Related Literature

Banks' motives for going abroad have several sources. Yannopoulos (1983), applying the eclectic paradigm of Dunning (1977) to multi–national banks, attributes the development and patterns of international bank activities to ownership, locational, and internationalization advantages. Ownership advantages are bank-specific characteristics, such as bank size and bank scope (degree of diversification across markets), which enable a particular bank to move beyond the domestic border. Locational advantages are host–country specific traits, such as profitability, regulatory and cost allowances, which attract foreign banks. In a context where international financial market returns are imperfectly correlated, banks which are diversified across foreign markets can enjoy better risk–return tradeoff on their portfolios than their domestic counterparts (Hymer, 1976). Internationalization advantage is the portfolio risk–return tradeoff improvement that multi–national banks can achieve as a result of the co–movement of international financial market returns. This chapter analyzes the roles of the ownership, locational and internationalization advantages simultaneously in banks' location and loan/deposit quantity choices.

The inclusion of initial (existing) bank size and bank scope among the determinants of banks' foreign portfolio choice captures the ownership advantage. As shown by Focarelli and Pozzolo (2000) and others, bank size, bank scope and efficiency are indeed the most important sources of bank ownership advantage. Furthermore, bank scope and bank size together sufficiently proxy for bank efficiency. Bank scope is the rate at which banks trade portfolio risk for return, and is measured using the lagged Sharpe ratio in this study. Bank scope is an ownership advantage since it is a bank–specific trait that enables banks to move beyond the domestic market. Furthermore, bank scope is also an internationalization advantage as it captures the extent to which banks can take advantage of the co–movement of returns across markets. An important — so far neglected — ownership advantage is bank risk aversion, which this analysis provides structural estimates for.

Initial bank size is defined as the total existing assets of a given bank. Bank size is an ownership advantage for several reasons. Demsetz and Strahan (1995) and Goldberg and Cetorelli (2008) show that greater size increases banks' propensity to enter new markets. On one hand, greater size enables banks to pay the fixed setup costs of expansion (Ursacki and Vertinsky., 1999). On the other hand, larger banks have an increased need for variance reduction (Pozzolo, 2008). In addition, bank size determines the amount of capitalization parent banks channel to their affiliates via internal capital markets (Goldberg and Cetorelli, 2009) — thereby having an impact on the quantities of banks' loan and deposit choices. The analysis of this chapter in unique in that it examines the roles of bank size and bank scope in banks' entry/exit and loan/deposit quantity choices simultaneously.

The mean–variance modeling framework employed in this study is in line with the conclusion of Focarelli and Pozzolo (2005) that the most promising context for examining international bank activities is one with portfolio optimization in the presence of fixed costs. In addition, the mean–variance portfolio choice framework (Markowitz, 1987) is useful because it factors the international correlation of market returns into banks' optimal decisions. Bank scope (defined as the lagged Sharpe ratio on banks' global portfolio) captures the extent to which banks can take advantage of these correlations to obtain a better risk–return tradeoff. Therefore, it is the mean–variance framework that allows the examination of bank scope as an internationalization advantage. Furthermore, the mean–variance portfolio choice formulation in this chapter is realistic, since past empirical research has verified that banks consider both portfolio mean and variance in their foreign activities. With respect to the role of expected returns (mean) in foreign banking, Demirguc-Kunt and Levine (1996) and Miller and Parkhe (1998) show that host country financial sector profitability is positively correlated with foreign bank operations there. Regarding the role of portfolio variance, Buch, Driscoll, and Ostergaard (2005) have shown that greater variance of asset returns is indeed a significant deterrent of banks' foreign activities.

The locational advantages of foreign banking are captured by including characteristics of host markets in the set of variables. These are measures of expected market return indices, competitiveness, entry barriers, regulations and costs. The importance of locational advantages has been well established in the literature. Looking at foreign banking activity within the United States, several studies (Grosse and Goldberg, 1991; Heinkel and Levi, 1992) have identified the significance of economic and regulatory factors. Papaioannou (2005) confirms the roles of legal and institutional factors in foreign bank activity. Miller and Parkhe (1998) claim that more stringent host country regulations deter foreign bank operations. Beyond regulations and costs, entry restrictions discourage foreign bank operations by acting as a type of fixed setup cost. Barth, Nolle, and Rice (1996) argue that host market entry restrictions limit the international flow of bank assets by eliminating diversification advantages. Buch, Driscoll, and Ostergaard (2005) show that capital controls in fact significantly reduce banks' ability to diversify into foreign markets. Furthermore, entry barriers put new entrants at a disadvantage compared to banks already present in the host market (Caves, 1987). This study contributes to the analysis of locational advantages in two ways. First, the analysis in this chapter presents structural estimates of each country's regulator's risk aversion parameter. Second, banks' observed behavior are used to estimate country–specific fixed entry costs and scrap values.

Foreign bank market competition is assumed to be monopolistically competitive. This choice is motivated by the fact that relationship banking is an important source of market power for banks. Relationships that banks develop with customers (Gray and Gray, 1981) provide them with informational capital, which translates into differentiated services (relationship banking) and market power. Greater market power is likely to affect both banks' entry/exit and loan/deposit quantity choices. Indeed, Focarelli and Pozzolo (2005) show that banks tend to expand into less competitive foreign markets. In addition to looking at the effect of market power in the foreign market entry choice, this study contributes to the existing research by examining the role of market power in banks' loan/deposit quantity choices as well.

The first type of decision this chapter addresses is banks' choices of foreign market entry/exit. Banks' dynamic foreign market entry/exit decisions shape the pattern of their global operations. As such, there has been extensive literature looking at the discrete entry (and more rarely, exit) choices, albeit in isolation from the volume decisions. In static probit analysis, past research has established the importance of locational factors (Cerutti, Dell'Ariccia, and Peria, 2006; Ferri and Pozzolo, 2008; Houpt, 1999; Miller and Parkhe, 1998; Nigh, Cho, and Krishnan, 1986; Sabi, 1988). Empirical studies have found that banks choose to build foreign affiliates because doing so gives them access to retail markets (Focarelli and Pozzolo, 2005) and hedge them against transfer risk (Cetorelli and Goldberg, 2009). However, previous literature has neglected the fact that static analysis is not adequate to analyze banks' inherently dynamic entry/exit choices. The analysis in this chapter examines these choices in a dynamic setting.

Careful study of the entry/exit decisions is especially important in light of recent global banking trends, showing that foreign operations via affiliates has been on the rise for the past two decades. During the 1990s, the rise in foreign affiliate banking via cross–border mergers and acquisitions was a global phenomenon (Berger, DeYoung, Genay, and Udell, 2001). During this period, U.S. banks' foreign affiliate assets also increased dramatically, rising from just 7 billion USD in 1970 to 718 billion USD by 1998. The increasing tendency of multi–national banks towards affiliate operations has had significant consequences for the financial structure of many host economies. In some Latin American and Eastern European countries, over 50 percent of banking assets are now foreign–controlled (Pozzolo, 2008).

The second type of decision under consideration here is banks' choice of the volumes of cross–border loans (generally flowing to sovereigns and multi–national corporations) and foreign affiliate loans (to retail clients). Both types have their advantages. On one hand, cross–border loans are advantageous in that they can draw on parent banks' capital base, and protect parent banks from foreign market political risk. Furthermore, Cerutti, Dell'Ariccia, and Peria (2006) show that banks prefer to make cross–border loans in foreign wholesale markets, and also to markets where corporate taxes are high. On the other hand, affiliate lending also has many advantages. Foreign affiliates provide limited liability to parent institutions. Cetorelli and Goldberg (2009) show that operating via foreign affiliates allows the activation of internal capital markets between parent banks and affiliates, which insulate banks from liquidity shocks in either the home or host countries. Affiliate activities also allow deposit–taking in foreign markets, which is not possible if lending is via cross–border loans (Saunders and Walter, 1994). Finally, foreign affiliate operations provide banks with potential tax advantages by delaying income repatriation Scholes and Wolfson (1992). Data show that U.S. banks have exhibited a striking tendency to move towards lending via affiliates. The largest U.S. banks' portfolio share of affiliate to cross–border loans had risen from 0.78 in 1997 to 1.35 by 2005.

2.3 Model

2.3.1 Setup and Notation

This section describes the model of banks' foreign market entry/exit and loan/deposit quantity choices. Let $j = 1...J$ denote bank j. Each bank j is owned by shareholders, whose goal is to maximize the lifetime discounted sum of mean–variance utilities on the bank portfolio. Shareholders make foreign market entry/exit, as well as loan/deposit quantity choices at the beginning of each period t. There are a total of T periods such that $t = 1....T$, and I countries such that $i = 1...I$. In what follows, the time indices are suppressed. Each bank j maintains presence in the domestic market, and chooses the composition of its foreign operations period by period.

Let subscript m index each market bank j participates in. In addition to lending and taking deposits in the domestic market, there are three markets in each foreign country i that bank j can engage in. These are the cross–border loan market, the affiliate loan market and the affiliate deposit market. Banks can make direct cross–border loans to any foreign country i, at the expense of a fixed cost Γ^i_{cb}. The cross–border loan market $m = cb$ consists of public and corporate borrowers. Cross–border loans come out of bank j's domestic budget, and are subject to domestic laws and regulations. Banks can also make loans and take deposits in country i's retail market $m = (a_l; a_d)$ by building a foreign affiliate in the country, at the expense of a fixed setup cost Γ^i_a. Foreign affiliate operations are financed out of each affiliate's separate budget, and are bound by country i's laws are regulations. The three available markets per country i are therefore $(a_l; a_d; cb)$. Since there is no cross–border lending in the domestic market, there are a total of 3 − 1 markets available.

The market specific setup costs are constant across banks and over time. Banks can recover the scrap values $\Psi^i_m < \Gamma^i_m$ if they decide to exit market m in country i. In the beginning of each period, bank j allocates its initial capitalization K_j across all markets it participates in. Since cross-border loans come out of the domestic budget, we can index initial allocated capital by country. Therefore, we have $K_j = \sum_i K^i_j$.

Banking clients in each market m demand a composite bundle of banking services from banks of all nationalities. Therefore, banking markets in each market m are monopolistically competitive, such that ϵ^i_m is the market–specific loan demand elasticity and η^i_m is the deposit supply elasticity. Banking clients in market m demand loans l^i_m and rate r^i_{lm}, and supply deposits d^i_m at rate r^i_{dm}[1]. Loan and deposit markets are subject to random and market–specific aggregate shocks. These shocks are captured by the market–specific composite lending and deposit rate indices, denoted by α^i_m and β^i_m respectively. These rate indices are composites of all banks' rates operating in market m, and are exogenous and random from bank j's perspective. Let bars above parameters denote period–by–period expectations, and V is the known and constant variance–covariance matrix of return indices[2]. Then

$$\begin{bmatrix} \alpha^i_m \\ \beta^i_m \end{bmatrix} - N \begin{bmatrix} \bar{\alpha}^i_m \\ ; V \\ \bar{\beta}^i_m \end{bmatrix} \tag{2.1}$$

Loan demand and deposit supply functions have the Dixit–Stiglitz type mo-

[1]Recall that no deposit-taking is possible in the cross–border market.

[2]These random variables are indices of all bank rates in market m, given by $\alpha_m = A_m \left[\int_n (r_{lmn})^{1-\epsilon_n} \partial n\right]^{-1}$ with $\epsilon_m > 1$ and $\beta_m = B_m \left[\int_n (r_{dmn})^{1+\omega_n} \partial n\right]$, where A_m and B_m are market–specific constants. The aggregation is over all banks of all nationalities operating in market m. Note that the U.S. bank takes these market indices as given.

nopolistically competitive form. Bank shareholders observe the loan demand l_m^i and deposit supply d_m^i functions:

$$l_m^i = \left(\frac{\alpha_m^i}{r_{lm}^i}\right)^{\epsilon_m^i} \qquad r_{lm}^i = \alpha_m^i (l_m^i)^{-1/\epsilon_m^i} \tag{2.2}$$

$$d_m = \left(\frac{r_{dm}}{\beta_m}\right)^{\eta_m} \qquad r_{dm} = \beta_m (d_m)^{1/\eta_m} \tag{2.3}$$

For each dollar's worth of loan l_m^i, the bank must incur a proportional (operational) lending cost of c_{lm}^i. Similarly, for each dollar's worth of deposit d_m^i the bank takes, it must incur a proportional (operational) cost of c_{dm}^i. Therefore, the per–dollar net interest income on l_m^i is $\left(r_{lm}^i - c_{lm}^i\right)$, and the per–dollar deposit expenditure is $\left(r_{dm}^i + c_{dm}^i\right)$.

In addition to loans and deposits, bank j can also borrow from other sources at known rates. Let Δ_m^i denote non–deposit net borrowing in market m (where $\Delta_{cb}^i = 0$). The rate $r_{\Delta m}^i$ at which the bank can borrow from other sources (such as the interbank market) increases in the amount of such borrowing, and decreases in the amount of initial capital that the bank allocates to market m in country i (never falling below the fixed rate $\bar{r}_m^i$) :

$$r_{\Delta m}^i = \bar{r}_m^i \left(1 + \frac{\Delta_m^i}{K_m^i}\right) \tag{2.4}$$

The *state variables,* which the bank observes in the beginning of each period are as follows. First, each bank observes its initial capital K_j. Second, the bank observes the vector of presence indicators $P_j = \left(P_a^1; P_{cb}^1; P_a^2; P_{cb}^2 ...; P_a^I; P_{cb}^I\right)_j$. These presence indicators are defined such that $P_m^i = 1$ if the bank already has operations in country i's market m at the beginning of the period, and $P_m = 0$ otherwise [3]. In addition to size and presence, the bank also brings its existing scope of operations into the current period, which results from its optimal actions in the preceding periods. This scope measures the extent to which the bank is able to trade return for risk, and is captured by the lagged Sharpe ratio S_j. Since loan and deposit return indices are random and correlated across markets, this scope measure S_j captures the extent to which the bank can benefit from any new entry/exit and investment choice.

The state variables $\left(P_j; S_j\right)$ depend on bank j's previous entry/exit and quantity choices. Since it is assumed that profits are re–distributed to shareholders at the end of each period t, total asset size K_j is taken to be exogenous from the bank's perspective. Further exogenous and known state variables of the model are: the vectors of proportional lending and deposit taking costs; the vector of taxes, capital and liquidity regulations (described below); the joint normal distribution of the return indices; the distribution of banks' private shocks, and the vectors of entry costs and scrap values, denoted by Γ and Ψ, respectively. Let Π denote the set of all state variables.

Shareholders' goal is to choose bank j's portfolio so as to maximize mean–variance utility over its end–period capital, denoted by $\tilde{K}_j$. Let $\tilde{K}_j^i$ denote the end–period capital in country i. Due to the random shocks affecting the loan demand and deposit supply functions, the country–specific $\tilde{K}_j^i$'s are also random variables. In each country i, $\tilde{K}_j^i$ is composed of the initial market capitalization K_j^i, plus net loan interest income, minus deposit and non-deposit borrowing expenditures, adjusted for the country–specific income tax t^i.

Recall that cross-border loans come out of bank j's domestic operations.

[3] Note that the subscript a refers to both affiliate loan and deposit markets

Fixed entry costs and scrap values appear in each affiliate's end–period capital. These fixed costs are relevant only if bank j enters or exits market m in the given period. Let $e^i_{mj}(\Pi) = 1$ denote bank j's decision to enter market m this period, and $e_{mj}(\Pi) = -1$ is the decision to exit, conditional on all the state variables. Then the domestic end–period capital is

$$\begin{aligned}\tilde{K}^{us}_j = K^{us}_j + (1 - t^{us}) \cdot (r_{la} - c_{la})^{us}_j \cdot (l^{us}_{aj}) - (r_d + c_d) \cdot d^{us}_j - \\ (r_{\Delta a} \cdot \Delta_a)^{us}_j + \sum_i \left(1 - t^i\right) \cdot (r_{lcb} - c_{lcb})^i_j \cdot \left(l^i_{cbj}\right) - \\ \sum_i \Gamma^i_{cb}\left(1 : e^i_{cbj} = 1\right) + \sum_i \Upsilon^i_{cb}\left(1 : e^i_{cbj} = -1\right) \quad (2.5)\end{aligned}$$

Foreign affiliate income is repatriated to the bank's domestic headquarters at the repatriation tax rate of ω^i. Then the country i foreign affiliate's end–period capital is[4]

$$\begin{aligned}\tilde{K}^i_j = K^i_j + \left(1 - t^i\right) \cdot \left(1 - \omega^i\right) \begin{bmatrix} (r_{la} - c_{la})^i_j \cdot l^i_a \\ - (r_d + c_d)^i_j \cdot d^i_j - (r_{\Delta a} \cdot \Delta_a)^i_j \end{bmatrix} - \\ \Gamma^i_a\left(1 : e^i_{aj} = 1\right) + \Upsilon^i_a\left(1 : e^i_{aj} = -1\right) \quad (2.6)\end{aligned}$$

After all foreign income is repatriated, bank j's end–period aggregate capital is $\tilde{K}_j = \sum_i K^i_j$.

Bank j's activities are subject to minimum reserve and risk–weighted capital requirements. Domestic and cross–border lending come out of the domestic budget, and are therefore bound by domestic (U.S.) regulations. Foreign affiliate operations are financed out of the budget of each foreign affiliate separately. Therefore, foreign affiliate operations are bound by each foreign country i's laws

[4]The loan revenue and deposit expenditure functions take the forms $r^i_{lm} \cdot l^i_m = \left(\alpha^i_m\right) \cdot \left(l^i_m\right)^{\frac{\epsilon^i_{m-1}}{\epsilon^i_m}}$ and $r^i_{dm} \cdot d^i_m = \left(\beta^i_m\right) \cdot \left(d^i_m\right)^{\frac{\eta^i_m + 1}{\eta^i_m}}$ respectively.

and regulations. Bank j can only operate (make loans and take deposits) in market i if it starts with positive initial capitalization $K_j^i > 0$. Let δ^i denotes the required reserve ratio, and $\bar{k}^i$ denote the fixed minimum capital ratio in market i. The budget constraints on bank j's domestic and foreign affiliate operations are

$$l_{aj}^{us} + \sum_i l_{cbj}^i \leq K_j^{us} + \Delta_{aj}^{us} + (1 - \delta^{us}) \cdot d_j^{us} \tag{2.7}$$

$$l_{aj}^i \leq K_j^i + \left(1 - \delta^i\right) \cdot d_j^i + \Delta_{aj}^i \tag{2.8}$$

The bank regulator in country i considers banks' risk–weighted capitalization in its capital requirement. Let θ^i denote country i's bank regulator's risk aversion parameter[5], and V^i is the variance–covariance matrix of the return indices in country i alone.[6] The risk–weighted capital requirements in the U.S. and country i are then

$$E\left[\tilde{K}_j^{us}\right] - \frac{\theta^{us}}{2} \cdot \left(\tilde{K}_j^{us\prime} V^{us} \tilde{K}_j^{us}\right) \geq \bar{k}^{us} \cdot \left(l_{aj}^{us} + \sum_i l_{cbj}^i\right) \tag{2.9}$$

$$E\left[\tilde{K}_j^i\right] - \frac{\theta^i}{2} \cdot \left(\tilde{K}_j^{us\prime} V^{us} \tilde{K}_j^{us}\right) \geq \bar{k}^i \cdot \left(l_{aj}^i\right) \tag{2.10}$$

The budget and regulatory constraints must hold in each period and each country. At this point it is useful to introduce time notation t.

Given the state $\Pi_t \in \Pi$, banks choose actions simultaneously. The two types of actions are the static loan/deposit quantity choices, and the dynamic foreign market entry/exit choices. Recall that $E_j = \left(e_{j1} ... e_{jT}\right)$ denotes bank j's actions, and let $E_t = (e_{1t} ... e_{Jt})$ denote the vector of time t actions. Then $E = (E_1 ... E_J)$.

[5]This risk aversion parameter denotes the weight that the regulator puts on the market risk on bank j's portfolio

[6]Note that the country–specific variance–covariance matrix of return indices V^i is *not* the same as the overall variance–covariance matrix on the bank's portfolio, denoted by V in Equation (2.15).

Before choosing its actions, each bank j receives a private shock ν_{jt}, drawn independently across banks and over time from a distribution $G_j(\cdot \mid \Pi_t)$ with support ν_j. The private shock might derive from variability in managerial drive for international portfolio diversification. Let the vector $\nu_t = (\nu_{1t}, ..., \nu_{Jt})$ denote private shocks of all banks.

Given its private shock, the entry/exit decision vector e_j and the set of state variables Π_t, bank j's utility takes the mean–variance form in each period t:

$$u\left(e_j, \Pi, \nu_j\right)_t = E\left(\tilde{K}_j\right)_t - \frac{\lambda}{2} \cdot \left(\tilde{K}_j' V \tilde{K}_j\right)_t \tag{2.11}$$

λ is the bank's constant risk aversion, common across all banks. Letting $\gamma < 1$ denote the constant discount factor, we can write bank j's discounted sum of utilities over time as:

$$E\left[\sum_{t=0}^{T} \gamma^t u_j\left(e_j, \Pi, \nu_j\right)_t \mid \Pi_t\right] \tag{2.12}$$

The expectation is over bank j's private shock in the current period, as well as future values of the state variables, actions, and private shocks. The final aspect of the model is the transition between states. The state vector at date $t+1$ is denoted by Π_{t+1}, and is drawn from a probability distribution $\Lambda(\Pi_{t+1} \mid e_t, \Pi_t)$. The dependence of this function on e_t means that time t entry/exit decisions affect the future strategic environment. However, not all states are influenced by past actions.

The analysis of equilibrium behavior focuses on *pure strategy Markov perfect equilibria (MPE)*. In a MPE, each bank's behavior depends only on the current state. Formally, a Markov strategy for bank j is a function ω_j: $\Pi \times \nu_j \mapsto E_j$. A profile of Markov strategies is a vector $\omega = (\omega_1, \ldots, \omega_J)$ where $\omega : (\Pi, \nu_1, \ldots, \nu_J) \mapsto E$. If behavior is given by a Markov strategy profile ω, bank j's expected utility over time, given a state Π can be written recursively:

$$V_j(\Pi,\omega) = E_\nu\left[u_j\left(\omega(\Pi,\nu),\Pi_t,\nu_{jt}\right) + \gamma\int V_j(\Pi';\omega)\,d\Lambda(\Pi' \mid \omega(\Pi,\nu),\Pi) \mid \Pi\right] \quad (2.13)$$

In (2.13), V_j is bank j's ex ante value function in that it reflects expected profits at the beginning of a period before private shocks are realized. The profile ω is a Markov perfect equilibrium if, given the opponent profile ω_{-j}, each bank j prefers its strategy ω_j to all alternative Markov strategies ω'_j.That is, ω is a Markov perfect equilibrium if for all banks j, states Π, and Markov strategies ω'_j,

$$V_j(\Pi,\omega) \geq V_j\left(\Pi;\omega'_j;\omega_{-j}\right) \quad (2.14)$$

It is assumed that all the conditions for the existence of such a MPE are satisfied.

2.3.2 Optimal Choices

Income from lending activities is redistributed to shareholders at the end of each period. Therefore, bank j's loan and deposit quantity choices can be analyzed in a static, period by period setting. Accordingly, in each period t bank j chooses its loan and deposit quantities to solve

$$\max_{l^i_{aj};l^i_{cbj};d^i_j\Delta^i_j;K^i_j} u\left(e_j,\Pi,\nu_j\right)_t = E\left(\tilde{K}_j\right)_t - \frac{\lambda}{2}\cdot\left(\tilde{K}'_jV\tilde{K}_j\right)_t \quad (2.15)$$

subject to the budget and regulatory constraints described in Equations (2.7) through (2.10). Banks make optimal foreign market entry and exit decisions that solve

$$\max_{e_{1j},\ldots,e_{Mj}} E\left[\sum_{t=0}^{T}\gamma^t u_j\left(e_j,\Pi,\nu_j\right)_t \mid \Pi_t\right] \quad (2.16)$$

Given the vector of fixed entry costs Γ and scrap values Υ, the optimal market entry and exit choices for a bank not in market i are as follows:

$$\begin{cases} \text{Enter} & \text{if } V_j\left(a^i_{mj}=1; a^i_{-mj}, \Pi, \omega\right) - \Gamma^i_m \geq V_j\left(a^i_{mj}=0; a^i_{-mj}, \Pi, \omega\right); \\ \text{Stay out} & \text{if otherwise.} \end{cases} \tag{2.17}$$

For a bank present in market i, the optimal decision rule is:

$$\begin{cases} \text{Exit} & \text{if } V_j\left(a^i_{mj}=-1; a^i_{-mj}, \Pi, \omega\right) + \Upsilon^i_m \geq V_j\left(a^i_{mj}=0; a^i_{-mj}, \Pi, \omega\right); \\ \text{Stay} & \text{otherwise.} \end{cases} \tag{2.18}$$

This concludes the characterization of bank j's optimal behavior. The next section describes how to use the structure presented above to estimate the determinants of banks' optimal decisions.

2.4 Estimation

The purpose of this section is to use the model described above to estimate how banks' choices of foreign loans, as well as their market entry/exit decisions depend on bank and market–specific characteristics. The goal is to recover the model's structural parameters. These parameters are: the utility function $u(\cdot)$, the discount factor γ, the transition probabilities $\Lambda(\cdot)$, the regulatory and bank risk aversion parameters (λ, θ), the tax rates and return indices (t, R), and the proportional and fixed costs/scrap values (c, Γ, Υ).

In what follows, it is assumed that the *unknown* structural parameters are the risk aversion parameters (λ, θ) and the fixed entry costs/scrap values (Γ, Υ). Let Θ denote the set of unknown structural parameters such that $\Theta = (\Gamma, \Upsilon, \lambda, \theta)$.

The goal of the following estimation is to recover these structural parameters from the model. The estimation strategy follows the Bajari, Benkard, and Levin (2007) (BBL) method of estimating dynamic games of imperfect competition. This method can estimate banks' dynamic strategic choices in this model without having to solve the dynamic optimization problem. The BBL method is based on two underlying assumptions. First is the assumption that the model described above represents banks' true behavior. Second, it is conjectured that the loan quantity and entry choices observed in the data result from banks' utility–maximizing actions, given the bank and country–specific characteristics (the state variables).

The estimation method consists of two parts. The first stage estimates bank j's optimal loan, deposit and entry/exit choices (the policy functions) as functions of the set of time t state variables. That is, the first stage estimates:

$$(l^*; d^*; e^*)_{jt} = f(\Pi_t) \tag{2.19}$$

where the * superscript denotes observed optimal choices, and Π_t is the set of state variables as of time t. The regression in Equation (2.19) yields policy function estimates $\left(\hat{l}; \hat{d}; \hat{e}\right)$ for any state variable Π_t. Plugging these estimates into $u_t(\cdot)$ produces the period by period value function. Transition probabilities for the state variables are also needed. The entry/exit estimate $\hat{e}$ is in fact the transition probability for bank j's presence vector P. Transition probabilities of the exogenous state variables can be estimated using observed data. As a result, state transition probability function estimates $\hat{\Lambda}(\Pi_{t+1} \mid \Pi_t)$ are obtained.

The second step uses the policy function estimates $\left(\hat{l}; \hat{d}; \hat{e}\right)$ together with the transition probability estimates $\hat{\Lambda}(\Pi_{t+1} \mid \Pi_t)$ to *forward-simulate* values for the discounted sum of utilities in (2.12). Recall that these estimates correspond to banks' optimal choices. Therefore, the resulting simulated value function corresponds to the value of banks' optimal behavior. Importantly, the resulting simulated values are still functions of the model's unknown structural parameters, such that $\hat{V}_j(\Pi;\omega;\Theta)$.

Given $\left(\hat{l};\hat{d};\hat{e}\right)$ together with $\hat{\Lambda}(\Pi_{t+1} \mid \Pi_t)$, forward simulation can also be used to evaluate *any other (alternate) bank strategy* ω'_j, with corresponding simulated values $\hat{V}_j(\Pi;\omega';\Theta)$. Based on the assertion that strategy ω_j is bank j's optimal behavior (described in Equation (2.14) above), the following inequality must hold at the true values of the structural parameters.

$$\hat{V}_j(\Pi;\omega;\Theta_0) \geq \hat{V}_j(\Pi;\omega';\Theta_0) \tag{2.20}$$

The second stage of the estimation then aims to find structural parameter estimates $\hat{\Theta}$ that minimize deviations from Equation (2.20). The detailed process of getting the policy function estimates $\left(\hat{l};\hat{d};\hat{e}\right)$ and the structural parameter estimates $\hat{\Theta}$ is described in the following subsections.

2.4.1 First Step: Policy Functions and Transition Probabilities

As described above, the first step consists of estimating banks' policy functions as functions of the period–specific state variables. The policy functions of interest are the discrete entry/exit choices, and the continuous loan and deposit quantity choices. Substituting estimates of these policy functions into the utility function reflects on how the value of bank operations depend on state variables.

Estimation of the loan/deposit quantity choices and the foreign market entry/exit decisions can be achieved in one step, via the *Heckman selection-bias-cor-*

rected Maximum Likelihood, or MLE estimation method. The advantage of using a maximum likelihood formulation is that it allows for estimating the policy functions in one step. Applying the Heckman selection correction method is important to ensure that the bias arising from correlation of the error terms in the entry/exit and loan/deposit quantity policy equations is accounted for. The MLE estimation consists of two equations. On one hand, Equation (2.21) estimates the probability that bank j is present in market i as functions of all the state variables at time t. Equation (2.22) estimates the loan and deposit quantity choices as functions of the time t state variables, conditional on bank j being present in country i at time t. Let $\Phi(\cdot)$ denote the CDF of the normal distribution, and Σ^i_{mt} denotes market characteristics at time t. Recall that K_{jt} and S_{jt} are bank j's initial capital and scope at time t, respectively. Then the estimable policy functions are:

$$\begin{aligned}
\text{Prob}\left(P^i_{mjt} = 1\right) &= \text{Prob}\left(\kappa_0 \cdot K_{jt} + \kappa_1 \cdot S_{jt} + \kappa_2 \cdot \Sigma^i_{mjt} + \kappa_3 \cdot \Gamma^i_m + \varepsilon^i_{mjt} > 0\right) \\
\text{Prob}\left(P^i_{mjt} = 1\right) &= \Phi\left[\kappa_0 \cdot K_{jt} + \kappa_1 \cdot S_{jt} + \kappa_2 \cdot \Sigma^i_{mjt} + \kappa_3 \cdot \Gamma^i_m\right]
\end{aligned} \tag{2.21}$$

$$\begin{pmatrix}
l^i_{ajt} = \pi_{a0} \cdot K_{jt} + \pi_{a1} \cdot \Sigma^i_{ajt} + \pi_{a2} \cdot S_{jt} + \pi_{a3} \cdot \theta^i + u^i_{jt} \\
l^i_{cbjt} = \pi_{cb0} \cdot K_{jt} + \pi_{cb1} \cdot \Sigma^i_{cbjt} + \pi_{cb2} \cdot S_{jt} + \pi_{cb3} \cdot \theta^i + \psi^i_{jt} \\
d^i_{ajt} = \pi_{d0} \cdot K_{jt} + \pi_{d1} \cdot \Sigma^i_{ajt} + \pi_{d2} \cdot S_{jt} + \pi_{d3} \cdot \theta^i + \upsilon^i_{jt}
\end{pmatrix} > 0 \quad \text{if } P^i_{jt} = 1 \tag{2.22}$$

$$\begin{pmatrix}
l^i_{jt} = 0 \\
l^i_{cbjt} = \pi_{cb0} \cdot K_{jt} + \pi_{cb1} \cdot \Sigma^i_{cbjt} + \pi_{cb2} \cdot S_{jt} + \pi_{cb3} \cdot \theta^i + \psi^i_{jt} \\
d^i_{ajt} = 0
\end{pmatrix} \quad \text{if } P^i_{jt} = 0, \tag{2.23}$$

In these policy equations, $(\kappa; \pi_a, \pi_{cb}; \pi_a)$ are vectors of estimable coefficients, and $(u, \psi; \varepsilon)$ are vectors of i.i.d error terms. Estimating this system of equations yields coefficient estimates $\hat{\phi} = (\hat{\kappa}; \hat{\pi}_a, \hat{\pi}_{cb}; \hat{\pi}_d)$. These estimates can be used to derive predicted optimal entry/exit, loan and deposit quantity choices for *any* combination of state variables Π. This is equivalent to obtaining estimates of the optimal strategies $\hat{\omega}(\Pi_t; \nu_t)$.

Estimation of the transition probabilities of the state variables in Π still remains. Recall from above the $e^i_{jt} = 1$ and $e^i_{jt} = -1$ denote bank j's decision to enter and exit market i at time t, respectively. From Equation (2.21), it is straightforward to get transition probability estimates such that

$$\begin{aligned} \text{Prob}\left(e^i_{mjt} = 1\right) &= \text{Prob}\left(P^i_{mjt} = 1 \mid P^i_{mjt-1} = 0\right) = \Phi\left(\cdot \mid P^i_{mjt-1} = 0\right) \\ \text{Prob}\left(e^i_{mjt} = -1\right) &= \text{Prob}\left(P^i_{mjt} = 0 \mid P^i_{mjt-1} = 1\right) = 1 - \Phi\left(\cdot \mid P^i_{mjt-1} = 1\right) \end{aligned} \tag{2.24}$$

Estimates for the exogenous transition probabilities of bank capital K_j can also be obtained from the empirical distribution. The distribution of K_j is normal. Therefore, Monte Carlo simulation with a normal target distribution can simulate values for initial capital K.

The next section describes how to get estimates of the unknown structural parameters Θ using the second step.

2.4.2 Second Step: Structural Parameter Estimates

Recall from above that the unknown structural parameters of interest are $\Theta = (\Gamma, \Upsilon, \lambda, \theta)$. Estimates $\hat{\Theta}$ are obtained from the second step of the estimation method. The process of recovering these structural parameters goes as follows. Using the estimated optimal strategies $\hat{\omega}(\Pi_t; \nu_t)$ from the first step:

$$\hat{V}_j(\Pi; \omega; \Theta) = E\left[\sum_{t=0}^{T} \gamma^t u_j\left(\hat{\omega}(\Pi_t; \nu_t), \Pi_t, \nu_{jt}; \Theta\right) \mid \Pi_0 = \Pi; \Theta\right]. \tag{2.25}$$

Estimate $\hat{V}_j(\Pi;\omega;\Theta)$ of the optimal value function can be obtained by forward–simulation using the estimated transition probabilities $\hat{\Lambda}(\cdot)$ as follows. Let N denote the total number of simulations. Based on the first–stage policy function estimates, bank j's corresponding estimated optimal entry/exit decisions and loan and deposit quantity choices — denoted by $\left(\hat{l};\hat{d};\hat{e}\right)$ — are calculated and plugged into $u_{jt}(\cdot)$. These steps are repeated for each of T periods, using the estimated transition probabilities to govern state transitions. Bank j's discounted sum of utilities is then averaged over the many simulated paths ($n = 1...N$) to yield the optimal value estimate $\hat{V}_j(\Pi;\omega;\Theta)$.

The same process can simulate values for a number of sub–optimal strategy paths ω'. Let $\hat{V}_j(\Pi;\omega';\Theta)$ denote the value estimates corresponding to these alternate strategies. The final step is to use the value estimates $\hat{V}_j(\Pi;\omega;\Theta)$ and $\hat{V}_j(\Pi;\omega';\Theta)$ to set up inequalities which ensure that the observed bank actions have the highest value. From Equation (2.20), it follows that

$$\hat{V}_j\left(\Pi;\omega_j;\omega_{-j};\Theta_0\right) \geq \hat{V}_j\left(\Pi;\omega';\omega_{-j};\Theta_0\right) \tag{2.26}$$

The goal is to obtain estimates $\hat{\Theta}$ to minimize violations of this set of inequalities. It is assumed that all conditions ensuring point identification are satisfied. If the set of inequalities characterizing the optimal choices is large enough and letting x denote the equilibrium conditions, the following function captures deviations from the set of inequalities in Equation (2.26):

$$g\left(x;\Theta;\hat{\phi}\right) = \hat{V}_j\left(\Pi;\omega_j;\omega_{-j};\Theta;\hat{\phi}\right) - \hat{V}_j\left(\Pi;\omega';\omega_{-j};\Theta;\hat{\phi}\right) \tag{2.27}$$

Let $g_n\left(x;\Theta;\hat{\phi}\right)$ be the value of this difference for the n'th simulation, when the first–stage policy function parameter estimates are $\hat{\phi}$. Let n_I denote the number of sub–optimal policy paths examined (i.e. the number of inequalities) for each simulation, and X_k denotes the k'th inequality. Recall that N is the total number of simulations. Then define

$$Q_n(\Theta) = \frac{1}{n_I} \cdot \sum_{k=1}^{n_I} \left(\min \left\{ g\left(X_k; \Theta; \hat{\phi} \right), 0 \right\} \right)^2 \tag{2.28}$$

The best estimates of the structural parameters Θ are such that

$$\hat{\Theta} := \arg\min_{\Theta} Q_n\left(\Theta; \hat{\phi}\right) \tag{2.29}$$

All conditions which ensure that this estimator is consistent and asymptotically normal are assumed to be satisfied.

The goal of the second stage estimation is to get country–specific estimates for the fixed entry costs Γ, scrap values Υ and regulatory risk aversion terms θ. Furthermore, the goal is to get one constant estimate for the bank risk aversion parameter λ. The following example gives an idea of the estimation process. If bank j exits country i at time t, the optimal value of this action is simulated. Then the values of *all other exit possibilities* are simulated, i.e. the value the bank would have obtained if it had exited at time $t = 0, 1, \ldots, T$. For each bank-country pair and each simulation n, this yields the values of a total of $n_I = 32$ sub–optimal paths. The country i–specific $Q^i_{jn}(\cdot)$ function for each simulation n is then calculated, yielding a 32 by 1 vector for each bank. Then variation across banks and simulation draws are used to obtain country-specific estimates $\left(\hat{\Gamma}^i; \hat{\Upsilon}^i; \hat{\theta}^i\right)$. The bank risk aversion parameter λ enters all countries' $Q^i_{jn}(\cdot)$ function. Thus line search is used to obtain the estimate $\hat{\lambda}$ from all the $Q^i_{jn}(\cdot)$ functions jointly.

It is important to take account of the fact that the first–stage policy functions are already functions of the unknown structural parameters that the second stage estimates. This difficulty is handled iteratively, as follows. At first, the second–stage set of inequalities are solved using the *observed* loan and deposit quantities and entry/exit decisions as inputs (as opposed to first–stage estimates). The resulting preliminary estimates of the structural parameters are then used as explanatory variables in the first–stage policy function regressions. The resulting policy function estimates are then used in the second stage to re–estimate the structural parameters. The process is repeated until the parameter estimates converge.

2.4.3 Data

The model's equations are estimated on a panel data set constructed from quarterly data on activities of U.S. banks in 46 foreign markets. The data cover the period between 1997 Q4 to 2005 Q4, a total of 33 quarters. Data on U.S. Banks' foreign claims and liabilities are from the Federal Financial Institutions Examination Council (FFIEC) Country Exposure Surveys. This quarterly survey reports on the foreign activities of U.S. banks with foreign exposure over 30 million USD broken down by host country. Data are reported separately for three bank size groups: Money Center Banks (large); Other Large Banks (medium) and All Other Banks (small). Data were collected from these surveys on U.S. banks' (1) domestic (U.S.) claims; and for each host country separately: (2) cross–border claims; (3) foreign affiliate claims, and (4) foreign affiliate liabilities.[7] The data are reported on an immediate counter–party basis, i.e. they do not take account of cross–country risk transfers. For each bank size category, the reported total claims and liabilities were divided by the number of banks to obtain the *average*loan and deposit quantities. This is necessary since the num-

[7] The reported survey data were converted into millions of USD, using 2005 Q4 as the base for inflation adjustment.

ber and total asset size of reporting banks change significantly over time within the panel.

With respect to the model parameters, data were collected on bank size (total assets) from the FFIEC Surveys described above. Data on the market–specific model parameters for the 46 host markets were gathered from various sources, including the International Monetary Fund (1997-2005)'s International Financial Statistics, Organisation for Economic Co-operation and Development (1997-2005)'s Statistics, the Economist Intelligence Unit (1997-2005)'s Country Data and the World Bank (1997-2005)'s Bank Regulation and Supervision database.

Initial values of the second stage estimation described in the earlier sections use bank and regulatory risk aversion parameter value estimates from the related literature. Previous papers have reported banks' risk aversion parameter (captured by λ) to be in the 0.20 (Nishiyama, 2007) to 0.29 (Kühn, 2006) range. For the entry costs, starting values come from regressing total costs on the total volume of activities for each country. The constant term from this regression provides a good initial value of the entry cost.

2.5 Estimation Results

2.5.1 Market Entry/Exit Choices and Loan/Deposit Quantities

This section describes the results of the static policy function estimations, which correspond to the first stage described above. The policy choices of interest are the affiliate loans, cross–border loans and deposits, as well as the entry and exit decisions in each country. The results of the Maximum Likelihood policy function estimation with the Heckman selection correction are presented in Tables 2.1 and 2.2.

The foreign market entry and exit results in Table 2.1. show that higher expected returns encourage entry and discourage exit. Furthermore, higher taxes, costs and stricter foreign market regulations discourage entry and increase the probability that banks leave the market. Both bank size and bank scope have strong positive impacts on the probability of entry, and significantly discourage exit. However, it is interesting to note that *the scope effect is more than twice as large as the size effect.* Regulatory risk aversions only have small and insignificant impacts on the entry/exit choices of banks. Higher entry costs significantly discourage entry, and greater scrap values increase the probability that banks exit the market.

The policy function estimates corresponding to the first stage of the estimation give strong confirmation of the importance of the selection bias in banks foreign activities. The correlation of the error terms of the selection and volume (quantity) equations is significant and positive with $\rho = 0.31^{***}(.02)$. This result implies that *on average, banks lend 32.98 percent more in selected markets, compared to a random sample of countries.* This significant and positive correlation, together with the fact that most explanatory variables impact both the entry/exit, as well as the volume choices, implies that the coefficient estimates suffer from serious upward bias. Specifically, running ordinary least squares regressions on the loan and deposit volumes (ignoring the selection bias) would lead us to overstate the impact of model variables. For instance, greater bank size makes banks more likely to enter a new market, and also increases the loan and deposit volumes, once there. OLS regression would therefore assign bank size a large coefficient, combining the impacts of size on entry and volume, conditional on entry. For comparison, the OLS coefficient estimate for the impact of bank size on affiliate loan volumes is 1.42, which is 12.7 percent higher than the true coefficient of 1.26 shown in Table 2.1. On average, affiliate loan volume coefficient estimates suffer from an upward selection bias of 12.72 percent, while the average bias in deposit coefficients is 12.47 percent.

Table 2.2 shows the bias-corrected coefficient estimates for banks' choices of cross–border loan, foreign affiliate loan and deposit volumes. Higher expected returns encourage banks to increase their loan volumes. Higher deposit financing costs have strong negative effects on deposit and affiliate loan volumes. This latter result confirms the importance of deposit–financing for affiliate loans. Stricter capital regulations have significant negative impacts on all foreign activities, with the strongest discouraging effect on affiliate loans. As expected, more competitive loan markets tend to increase loan volumes. It is surprising that deposit volume decreases as banks face more elastic deposit supply curves. Both bank size and bank scope have strong positive impacts on loan and deposit volumes. It is interesting that bank scope has over three times as large an impact as bank size. This difference is most expressed for cross–border loan volumes, where the scope effect is over eight times the size of the bank size effect.

In what follows, the transition probabilities for the presence vector P are constructed using coefficient estimates from Table 2.1. The paths for bank asset size K_j are constructed using Monte Carlo draws from the empirical normal distribution with the following bank size–specific moments. For small banks, the empirical distribution is characterized by $N(10, 0.07)$. For the medium-size

Table 2.1: Foreign Market Entry & Exit Probabilities: Elasticities.

Explanatory Variables	Entry Probability	Exit Probability
Exp Affil Loan Rate	0.86^{*}(.49)	-0.03^{*}(.02)
Exp Deposit Rate	-0.32 (1.01)	0.01 (.04)
Income Tax Rate	-2.57^{***}(.49)	0.10^{***}(.02)
Lending Cost	-0.08^{**}(0.04)	0.01^{**}(.00)
Minimum Capital Ratio	-1.44^{***}(.31)	0.05^{***}(.01)
Required Reserve Ratio	-0.01 (.04)	0.01 (.00)
Lagged Bank Size	0.73^{***}(.04)	-0.03^{***}(.00)
Affil Loan Demand Elast	0.28^{***}(.05)	-0.01^{*}(.00)
Deposit Supply Elast	-0.08^{**}(.04)	0.01^{**}(.00)
Lagged Sharpe Ratio	1.70^{**}(.78)	-0.06^{**}(.03)
Regulatory Risk Aversion	-0.01 (.05)	0.01 (.00)
Fixed Entry Cost	-0.20^{**}(.09)	0.01^{**}(.00)
Fixed Scrap Value	0.06^{*}(.04)	0.01^{***}(.00)

Table 2.2: Loan & Deposit Quantity Choices: Elasticities.

Explanatory Variables	CB Loan	Affil. Loan	Deposit
Exp Affil Loan Rate	2.80^{***}(.72)	1.37^{***}(.37)	0.34 (0.34)
Exp Deposit Rate	0.05^{**}(.02)	-3.35^{***}(0.63)	-3.55^{***}(.59)
Income Tax Rate	-1.60^{***}(.29)	-1.66^{***}(.13)	1.66^{***}(.13)
Lending Cost	-0.11^{***}(.03)	-0.41^{***}(0.05)	-2.08 (4.02)
Deposit Cost	-0.73 (0.74)	-2.80 (3.81)	-0.25^{***}(.05)
Minimum Capital Ratio	-0.72^{***}(0.31)	-0.91^{***}(.30)	-0.04 (.31)
Required Reserve Ratio	-0.27^{***}(.02)	0.51^{***}(.07)	0.22^{***}(.06)
Lagged Bank Size	0.81^{***}(.05)	1.26^{***}(.13)	1.25^{***}(.14)
Affil Loan Demand Elast	0.20^{***}(.08)	0.12^{***}(.03)	0.04 (.03)
Deposit Supply Elast	-0.48^{***}(.05)	-0.13^{***}(.03)	-0.04^{*}(.03)
Lagged Sharpe Ratio	6.53^{***}(1.04)	3.30^{*}(2.00)	3.91^{**}(2.03)
Regulatory Risk Aversion	0.38^{***}(.04)	-0.17^{***}(.06)	-0.04 (.07)

category, the distribution is $N(10.8, 0.17)$, and for large banks it is $N(13.7, 0.12)$.

2.5.2 Risk Aversion, Market Entry Costs and Scrap Values

This subsection describes the estimation results for the remaining structural parameters of the model. These parameters are: banks' constant risk aversion parameter λ (common across all banks), the country–specific regulatory risk aversion parameters θ^i, and the country–specific entry costs Γ^i and scrap values Υ^i (which are common across banks and constant over time). The estimates presented in the following tables result from the second stage of the estimation.

It is important to emphasize that the estimation aims to capture entry costs and scrap values that are *fixed* — i.e. fundamentally independent of the scope and scale of banks' activities in each market. However, costs associated with branch network building are inherently proportional to the scale of banks' activities. Therefore, *proportional total operating costs (including branch network costs) are subtracted from interest revenue*, in order to make the fixed cost estimates scale–independent. The estimate for the bank risk aversion parameter is $\lambda = 0.34^{***}(.00)$. Table 2.3 presents the fixed entry cost, scrap value and regulatory risk aversion parameter estimates for each country in the sample, and Table 2.4 examines how estimates correlate with economic and regulatory measures.

As shown in Table 2.5, scale–independent entry costs and scrap values are moderate with averages of 1.12 and 0.56 million USD, respectively. Entry costs and scrap values show clear regional patterns. Table 2.3 shows that entry costs appear to be the highest in the Eastern European countries — notably in Hungary, the Czech Republic and Russia. These costs are also above average in the South–East Asian economies, and appear low in most European countries and the rest of the developed world. The scrap values are consistently lower than the entry cost estimates, as expected. Scrap values are positively correlated with entry costs in the OECD states. In developing countries, however, higher entry costs are accompanied by average scrap values. Scrap values are generally higher in markets where market exit was observed, highlighting the positive relationship between scrap values and market exit (also documented in Table 2.1).

Table 2.3 also presents the estimated regulatory risk aversion parameters. Table 2.5 shows that with a mean risk aversion parameter estimate of 0.52, regulators are generally more risk averse than banks. Regulatory risk aversion estimates are the highest in the South American states, while European and North American regulators appear to have risk aversions below average.

Table 2.3 shows that for the South American countries in the sample, variation in the simulated data was not sufficient to provide entry cost estimates. The forward simulation was successful in getting estimates for most countries' regulatory risk aversion and scrap values.

Table 2.3: Estimates of Entry Costs, Scrap Values (Millions of 2004 Q4 USD) and Risk Aversions.

Country	Entry Cost	Scrap Value	Reg. Risk Aversion
Argentina	–	0.94^{***}(.03)	1.19^{***}(0.29)
Australia	0.87^{***}(.03)	0.09^{***}(.01)	0.31^{***}(.11)
Austria	0.29^{***}(.01)	–	0.35^{***}(.06)
Belgium	0.77^{***}(.10)	0.44^{*}(.23)	0.25^{**}(.14)
Brazil	–	1.29^{***}(.42)	0.40(.43)
Bulgaria	0.70^{***}(.03)	0.60^{***}(.02)	0.78^{***}(.18)
Canada	0.85^{***}(.10)	0.31(.57)	0.24(.41)
Chile	–	0.79(.74)	0.70^{***}(.22)
China	0.43^{***}(.03)	0.04(.03)	0.75(.56)

Table 2.3: (Continued)

Country	Entry Cost	Scrap Value	Reg. Risk Aversion
Columbia	–	0.41^{***}(.01)	0.79(.71)
Czech Rep.	4.23^{***}(.10)	0.64^{***}(.06)	0.01^{***}(.00)
Denmark	0.90^{***}(.03)	–	0.51^{***}(.06)
Finland	0.93^{***}(.03)	0.12^{***}(.01)	0.50^{***}(.06)
France	0.85^{***}(.05)	0.77^{***}(.02)	0.70^{***}(.14)
Germany	1.12^{***}(.08)	0.11^{***}(.02)	0.43^{***}(.12)
Greece	–	0.88^{***}(.14)	0.52^{*}(.30)
Hungary	2.05^{***}(.16)	0.65^{***}(.02)	0.03(.24)
Iceland	–	1.60^{***}(.08)	0.59(.63)
India	1.59^{***}(.17)	1.20^{***}(.14)	0.20^{***}(.07)
Indonesia	–	1.12^{***}(.24)	0.42^{*}(.28)
Ireland	0.93^{***}(.04)	0.26^{***}(.01)	0.45^{***}(.06)
Israel	–	0.71^{***}(.04)	0.49(.58)
Italy	0.87^{***}(.03)	0.83^{***}(.03)	0.52^{***}(.06)
Japan	0.94^{***}(0.08)	0.13^{***}(.03)	0.40^{***}(.12)
Luxembourg	1.01^{***}(.09)	0.11^{***}(.02))	0.33^{***}(.10)
Malaysia	0.30^{***}(.01)	0.02^{***}(.01)	0.90 (.60)
Mexico	0.85^{***}(.04)	0.12^{***}(.01)	0.68^{***}(.12)
Netherlands	0.30^{***}(.01)	0.03^{***}(.01)	0.63 (.68)

Table 2.3: (Continued)

Country	Entry Cost	Scrap Value	Reg. Risk Aversion
New Zealand	0.98***(.06)	0.11***(.01)	0.42***(.09)
Norway	0.89***(.03)	0.13***(.01)	0.49***(.06)
Philippines	–	1.19***(.06)	0.64***(.10)
Poland	–	0.98***(.05)	0.56***(.13)
Portugal	–	1.10***(.30)	0.42 (.39)
Romania	–	0.96***(.09)	0.60***(.19)
Russia	5.16***(.39)	0.89**(.29)	1.06 (1.21)
Slovakia	–	0.97***(.08)	0.64***(.19)
South Africa	–	0.88***(.15)	0.57*(.33)
South Korea	1.05***(.08)	0.11***(.02)	0.36***(.10)
Spain	0.87***(.03)	0.10 (.01)	0.46***(.06)
Sweden	0.88***(.04)	0.13***(.00)	0.48***(.06)
Switzerland	0.80***(.02)	0.09***(.00)	0.54 (.38)
Thailand	0.17***(.01)	0.04***(.01)	0.71 (1.14)
Turkey	–	1.12***(.22)	0.43 (.31)
United Kingdom	0.86***(.07)	0.14***(.03)	0.50***(.14)
United States	–	–	3.91 (13.6)

Table 2.4 correlates the parameter estimates with numerous empirical indicators of bank profitability, efficiency, economic openness and political and reg-

ulatory background. Estimated entry costs are significantly higher in markets that are inefficient, profitable, risky, have a greater share of government ownership, and where the banking sector is less developed. Scrap values show the same pattern. It is interesting that the gap between entry costs and scrap values is greater in markets that are more profitable with less developed banking sectors. The regulatory risk aversion estimates are significantly higher in markets that are inefficient and less developed. Higher overhead costs in markets with more risk averse regulators might be due to a greater burden of compliance. Furthermore, regulatory risk aversion estimates are strongly positively correlated with other measures of bank regulations, such as minimum capital ratios and liquidity regulations. Regulators appear more risk averse in markets where they have less corrective power with respect to existing regulations.

Table 2.4: Correlations with Economic and Regulatory Measures.

Measures	Entry Cost	Scrap Value	Entry-Scrap	Reg. Risk A.
Entry Cost	1.00			
Scrap Value	0.55	1.00		
Entry Minus Scrap	0.96^{***}	0.29	1.00	
Reg. Risk Aversion	−0.07	0.06	−0.05	1.00
Cap-Acct Open-Index	−0.22	-0.35^{**}		0.01
Distance from U.S.	−0.04	−0.06	−0.03	−0.02

Table 2.4: (Continued)

Measures	Entry Cost	Scrap Value	Entry-Scrap	Reg. Risk A.
Common Language	−0.05	−0.07	−0.10	−0.22
Average Total Costs	0.40**	0.05	0.42**	−0.28*
Avg Overhead Costs	0.52***	0.47***	0.53***	0.43***
Total Banking Cost	−0.14	−0.13	−0.16	−0.13
ICRG Comp Risk	−0.36**	−0.60***	−0.21	−0.28*
ICRG Fin. Risk	−0.12	−0.55***	−0.07	−0.16
Govt ownship Share	0.49***	0.52***	0.37*	0.12
Bank Development	−0.45***	−0.62***	−0.35*	−0.07
Net Interest Margin	0.55***	0.61***	0.53***	0.14
Nonperf. Loan Share	0.43***	0.17	0.37	0.15
Socialist Legal Origin	0.70***	0.18	0.70***	−0.02
OECD Member	−0.16	−0.37**	−0.11	−0.47***
Corrective Power	−0.11	0.26	−0.12	−0.52***
Min. Capital Ratio	0.24	0.46**	0.17	0.28*
Req. Reserve Ratio	0.07	0.19	−0.02	0.32**

Table 2.5: Summary Statistics For Estimation Results.

Estimates	Min	25p	50p	75p	Max	Mean	Std Dev
Reg. Risk Aversion	0.01	0.42	0.50	0.64	1.19	0.52	0.23
Entry Cost	0.17	0.80	0.88	1.01	5.16	1.12	1.05
Scrap Value	0.02	0.11	0.44	0.94	1.91	0.56	0.49

2.6 Simulation Exercises

This section conducts four types of exercises. Subsection 2.6.1.examines the effect on banks' optimal behavior of gradually increasing the bank risk aversion parameter λ, while holding all countries' regulatory risk aversion parameters constant at their estimated values. Subsection 2.6.2 examines the effects of increasing all foreign countries' risk aversion parameters simultaneously, holding the bank risk aversion λ and the U.S. regulatory risk aversion constant at their estimated values. Subsection 2.6.3 analyzes the impact of gradual increases in the U.S. regulator's risk aversion parameter, while holding λ and all other markets' regulatory risk aversion constant. Recall that bank risk aversion is the weight banks put on the variance of their global portfolios. Furthermore, foreign regulatory risk aversion is the weight each country's bank regulator puts on the variance of banks' country–specific portfolios. Finally, U.S. regulatory risk aversion is the weight the U.S. bank regulator attaches to the variance of U.S. banks' domestic portfolios.

2.6.1 Increasing Bank Risk Aversion

Figures 2.1 through 2.4 show the effects of raising the bank risk aversion parameter λ from 0.001 to 4, holding all regulatory risk aversion parameters constant at their estimated values. For each λ, the value of the banks' problem is evaluated

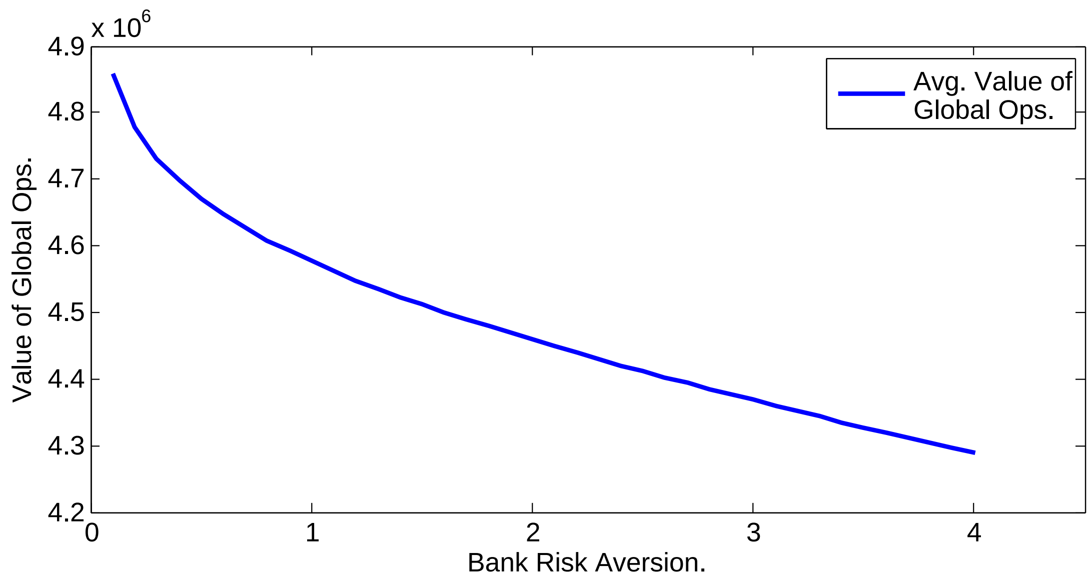

Figure 2.1: Value of Banks'Global Portfolio as Function of Bank Risk Aversion.

at the corresponding fixed entry costs and scrap values.

Figure 2.1 shows that λ has a strong negative impact on the value of the bank's global operations. As λ increases from 0.001 to 4, the bank's simulated value falls 12 percent. Figure 2.2 depicts the effect of increases in λ at the average country level. Figure 2.2 shows that both the value of banks' U.S. operations, and the average value of foreign country–specific operations are negatively affected. As λ increases from 0.001 to 4, the value of U.S. operations falls 5.1 percent, while the average value of foreign country operations falls 5 percent. It

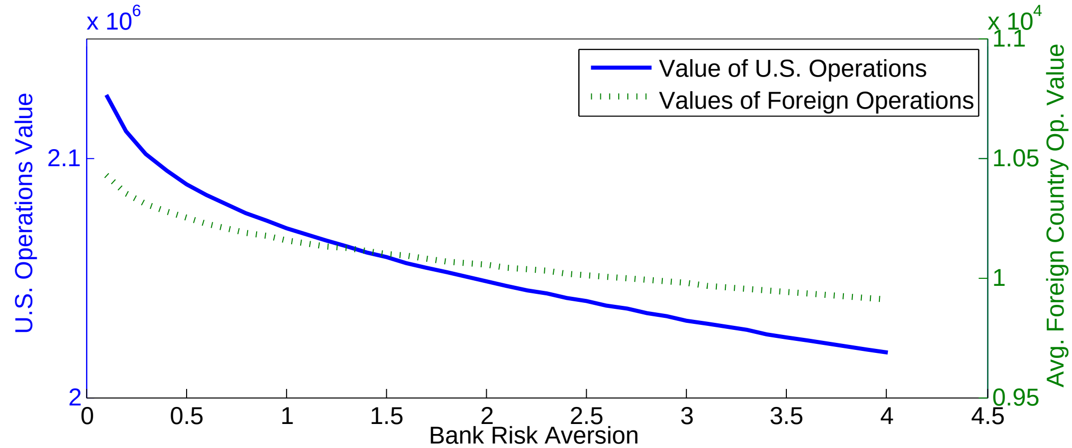

Figure 2.2: Values of Bank's U.S. Operations (Left Scale) and Average Foreign Country Operations (Right Scale) as Function of Bank Risk Aversion.

is interesting to take note of Figure 2.3, which shows the effect of increases in λ on the share of foreign assets that the bank chooses in its portfolio. Figure 2.3 shows that as λ increases from 0.001 to 4, the share of foreign assets in the bank's portfolio *rise* 15.1 percent. A potential explanation for this result is that as banks become more risk averse, they become more reluctant to take on riskier U.S. loans. Instead, banks look towards the less risky foreign assets. Within foreign assets, Figure 2.4 shows that banks move towards cross–border loans relative to affiliate loans as they become more risk averse. The graph shows that as λ increases from 0.001 to 4, the ratio of affiliate to cross–border loans falls 1.5 percent. This makes sense in light of the fact that cross–border loans generally target multi–national corporations and sovereigns — characterized by lower risk than the retail and smaller corporate clients that affiliate loans target.

Figure 2.5 is an interesting reflection on the suitability of the model for analyzing bank behavior far from equilibrium values. The graph depicts the effect

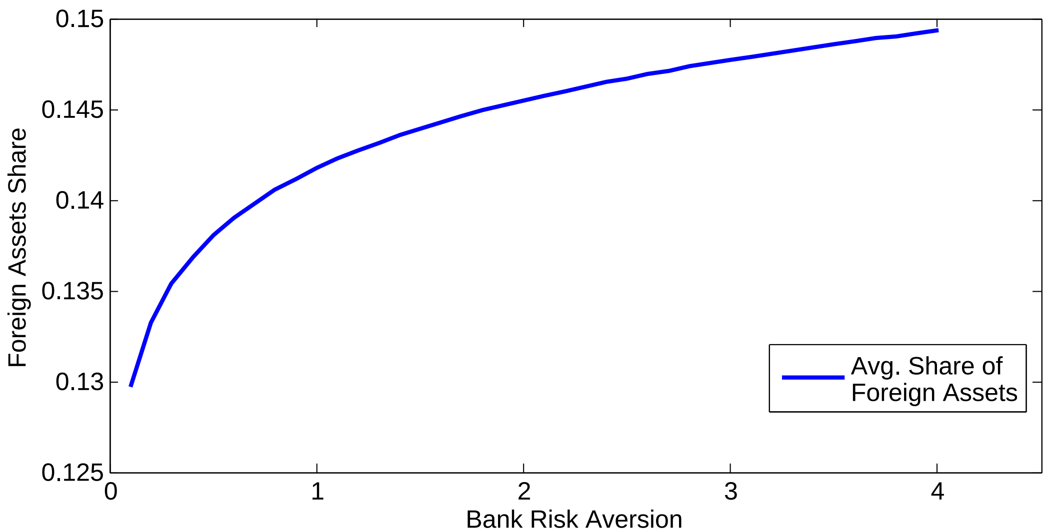

Figure 2.3: Share of Foreign Assets in Bank's Portfolio as Function of Bank Risk Aversion.

of increases in λ on the estimated average fixed costs of entry and scrap values. The graph shows that these estimated costs and scrap values remain constant until λ reaches 2.4, and increase sharply thereafter. As λ increases from 2.4 to 4, average estimated fixed entry costs rise 23 percent, and scrap values increase by 65 percent. In light of the fact that there is no reason to expect fixed costs and scrap values to vary with λ, Figure 2.5 shows that the model behaves well up to approximately eight times the equilibrium value of $\lambda = 0.34$. Beyond that, however, the model produces unreliable results.

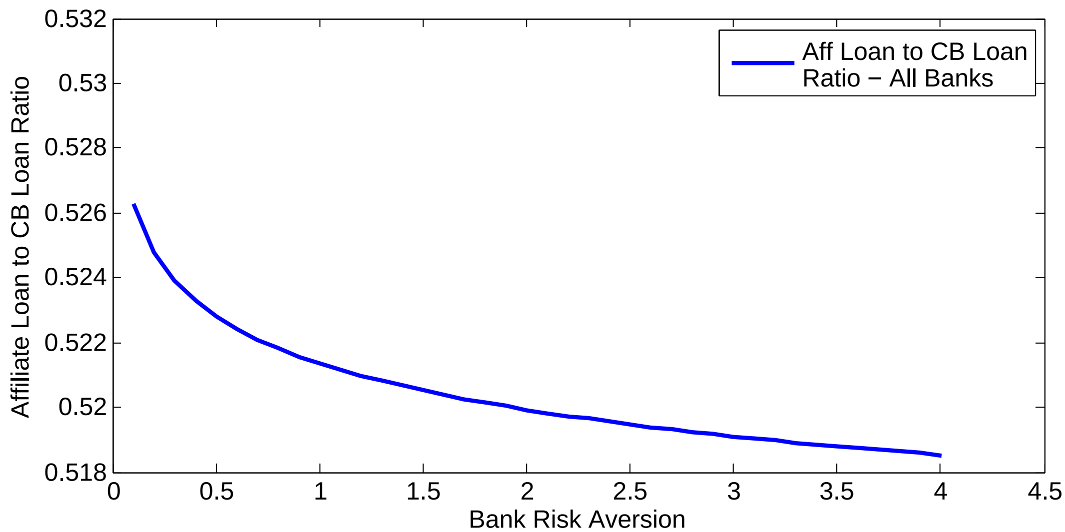

Figure 2.4: Ratio of Affiliate Loans to Cross-border Loans in Bank's Portfolio as Function of Bank Risk Aversion.

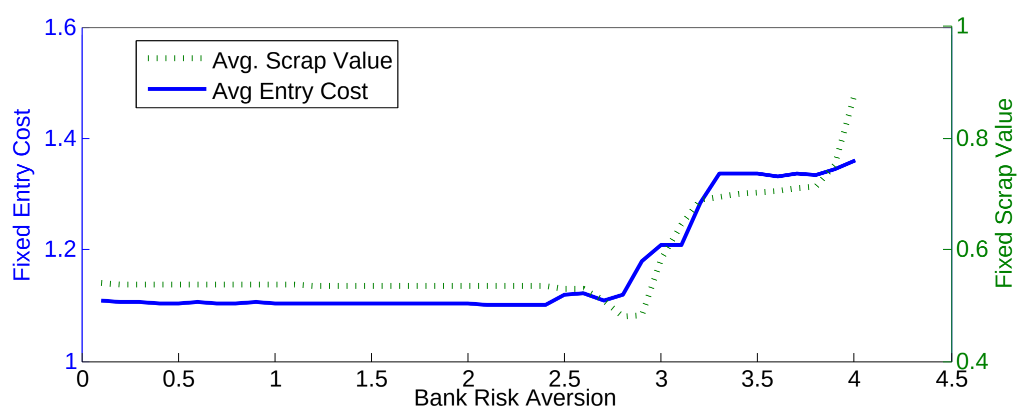

Figure 2.5: Average Estimated Fixed Entry Costs and Scrap Values as Function of Bank Risk Aversion.

2.6.2 Increasing Foreign Regulatory Risk Aversion

Regulatory and bank risk aversion work through different channels; bank risk aversion through the objective function and regulatory risk aversion through a constraint. This subsection explores the effects of varying all foreign markets' regulatory risk aversions simultaneously, while keeping the bank risk aversion and U.S. regulatory risk aversion parameters constant at their estimated values.

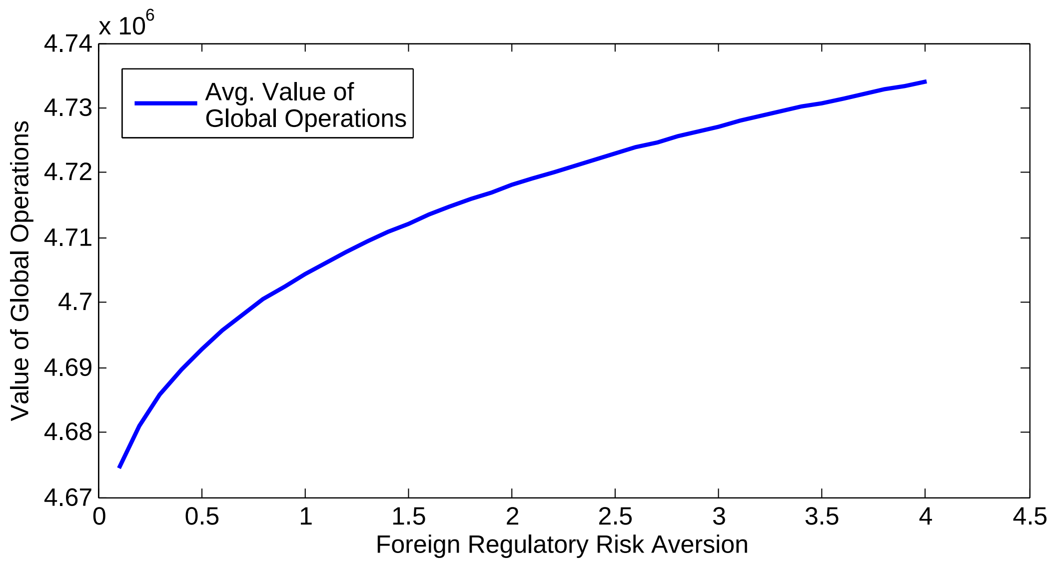

Figure 2.6: Value of Banks' Global Portfolio as Function of Foreign Regulatory Risk Aversion.

Figure 2.6 shows that as all foreign markets' regulatory risk aversions increase from 0.001 to 4, the value of global operations *increases* moderately by 1.3 percent. Figure 2.7 shows that a similar increase in foreign θ causes the value of the bank's U.S. operations to increase slightly by 1.9 percent, and the value of the average foreign country operation to fall by 3.6 percent. Figure 2.8 depicts the strong negative relationship between foreign θ and the share of foreign assets in the bank's portfolio. As foreign θ increases from 0.001 to 4, the share of foreign assets falls by 21.4 percent. Therefore, stricter foreign bank regulations cause U.S. banks to adopt a much more domestic focus.

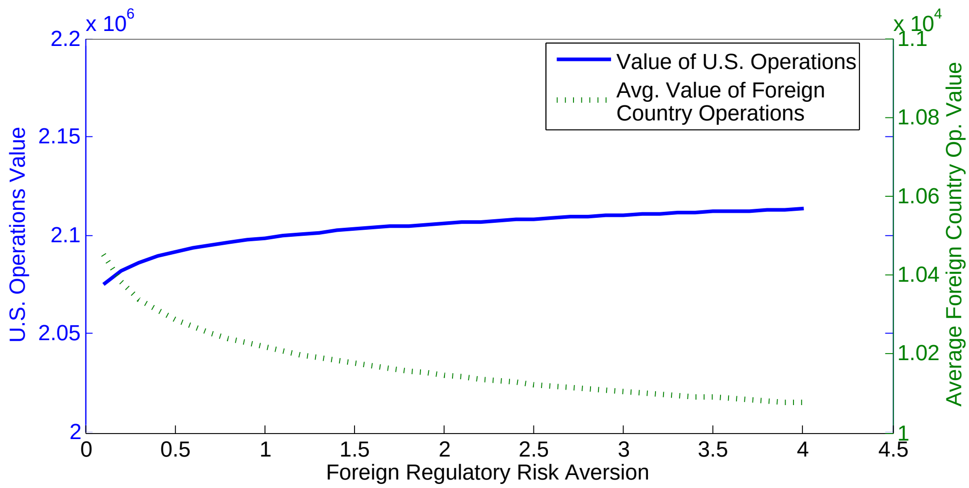

Figure 2.7: Values of Banks' U.S. Operations (Right Scale) and Average Foreign Country Operations (Right Scale).

Figure 2.9 depicts the effect of increases in foreign θ on the ratio of affiliate loans to cross–border loans in the bank's portfolio. As foreign θ rises up to 4, this ratio decreases significantly by 40.3 percent. Therefore, while stricter foreign regulations lower foreign participation of U.S. banks altogether, foreign affiliate assets take a much greater hit relative to cross–border loans. This result is likely due to the fact that affiliate loans are generally under foreign regulators' supervision, while the regulation of cross–border loans is often shared by the U.S. and foreign regulators. Therefore, a stricter foreign regulatory framework affects affiliate assets to a greater extent.

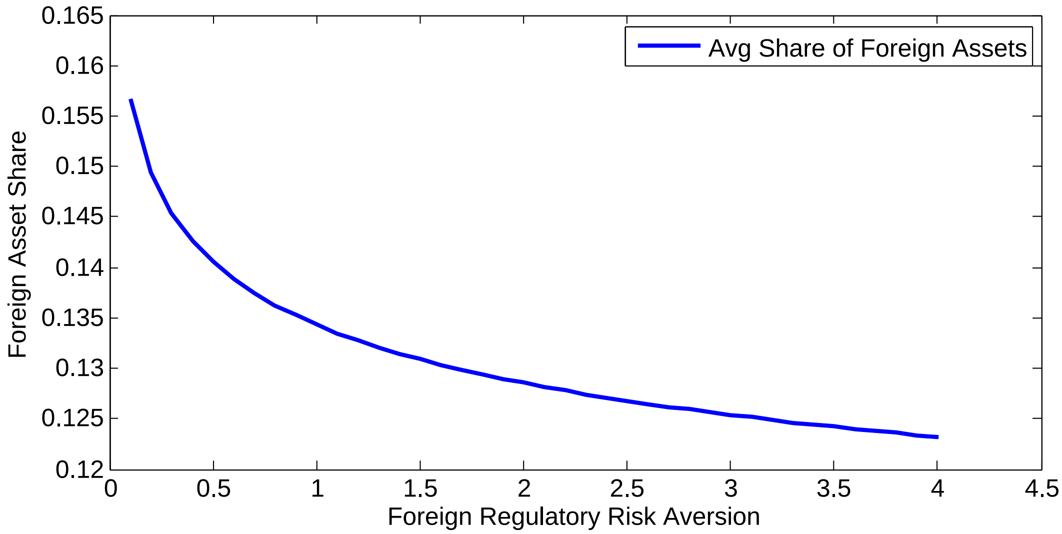

Figure 2.8: Share of Foreign Assets in Banks' Portfolio as Function of Foreign Regulatory Risk Aversion.

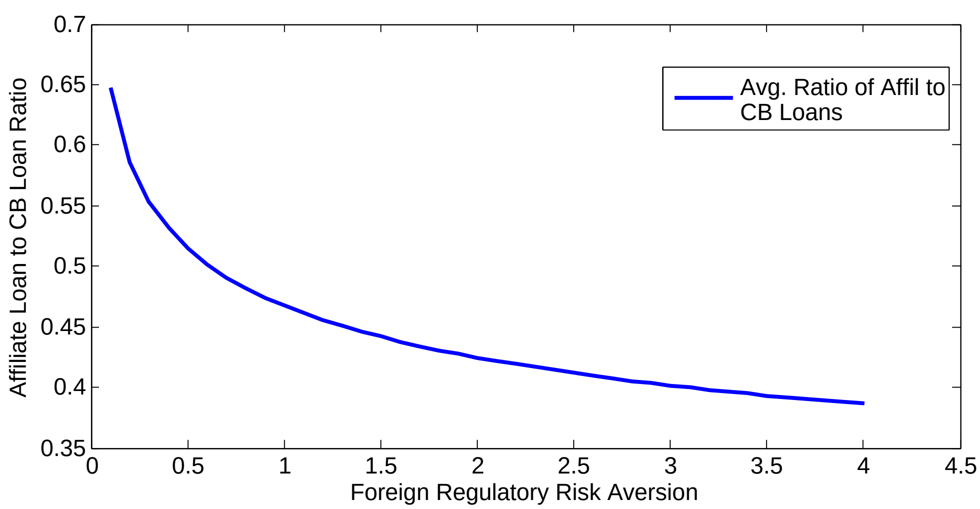

Figure 2.9: Ratio of Affiliate Loans to Cross-border Loans in Banks' Portfolio as Function of Foreign Regulatory Risk Aversion.

2.6.3 Increasing U.S. Regulatory Risk Aversion

This chapter focuses on the behavior of U.S. banks exclusively. Therefore, it is particularly interesting to analyze how banks' optimal behavior changes, as the U.S. regulators become more risk-averse. This subsection explores the effects of increasing the risk aversion of U.S. regulators on banks' optimal behavior. In this exercise, bank risk aversion and all other markets's regulatory risk

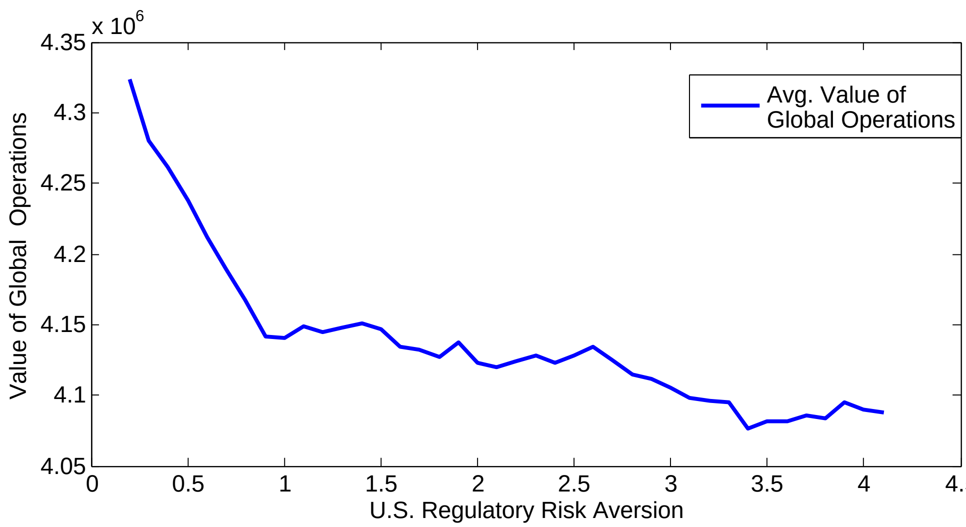

Figure 2.10: Value of Banks' Global Portfolio as Function of U.S. Regulatory Risk Aversion.

aversions are held constant at their estimated values. Figure 2.10 shows the relationship between the simulated value of the bank's global operations as the U.S. regulatory risk aversion θ increases from 0.001 to 4. This increase in U.S. θ causes the value of the bank's global operations to fall by 5.5 percent. Figure 2.11 focuses on the country–specific effects of the increase in U.S. θ, depicting the results for the value of U.S. operations and the value of the average foreign

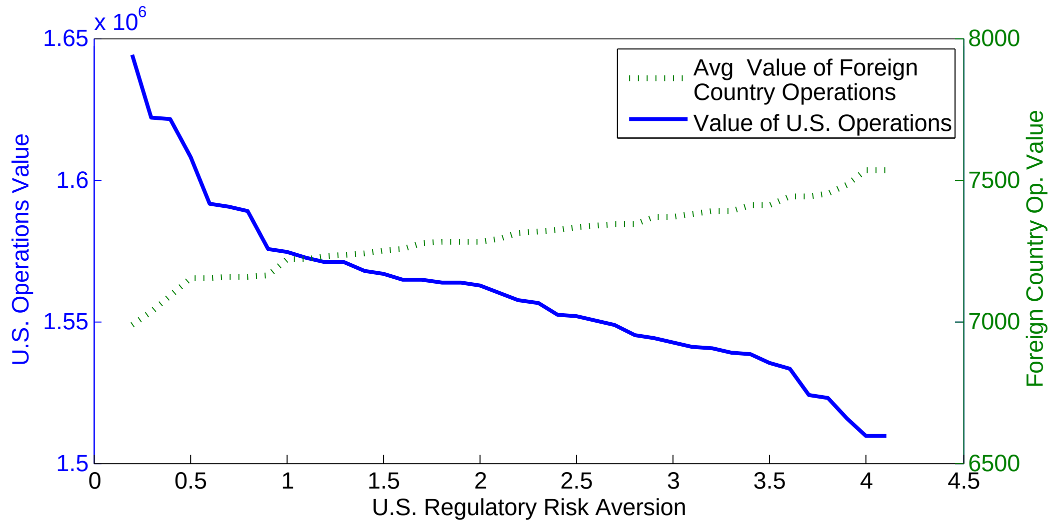

Figure 2.11: Value of Banks' U.S. Operations (Left Scale) and Average Foreign Country Operations (Right Scale).

country operations. The increase in U.S. θ from 0.001 to 4 causes the value of U.S. operations to fall by 8.2 percent, and the value of the average foreign country operation rises by 7.9 percent.

It is interesting to note Figure 2.12's depiction of the strong positive relationship between the share of foreign assets in the bank's portfolio and U.S. θ. As U.S. θ increases from 0.001 to 4, the share of foreign assets in the bank's global portfolio increases by 38 percent. Therefore, a stricter U.S. bank regulatory environment causes U.S. banks to take a more international focus. An increase in U.S. θ from 0.001 to 4 does not have a notable impact on the ratio of affiliate loans to cross–border loans in the bank's global portfolio.

It is also insightful to compare and contrast how U.S. banks' foreign focus responds to changes in U.S. versus foreign regulatory strictness. Based on the last two simulation exercises, it appears that stricter U.S. regulations encourage U.S.

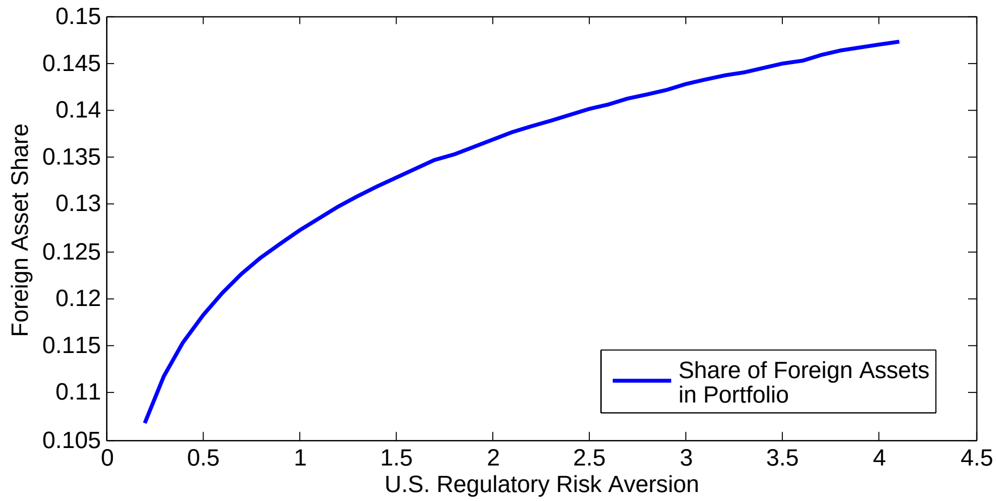

Figure 2.12: Share of Foreign Assets in Banks' Portfolio as Function of U.S. Regulatory Risk Aversion.

banks' foreign participation to a greater extent than stricter foreign regulations discourage them. However, foreign regulations have a very strong impact on the composition of U.S. banks' foreign portfolio (greatly discouraging affiliate lending), while U.S. regulations play only a very small role in these considerations.

2.7 Summary

This chapter examines the determinants of U.S. banks' international portfolio choices, with the goal of recovering the underlying structural parameters that shape these decisions. It presents a dynamic model of mean–variance utility maximizing monopolistically competitive bank behavior. Banks make period–by–period choices of optimal domestic, cross–border and foreign affiliate loan and deposit quantities. In addition, banks make foreign market entry/exit decisions considering their lifetime utility. All these decisions are bound by budget and regulatory constraints, and depend on period–specific state variables such as bank characteristics (initial size and scope) and market traits (return indices, correlations, proportional costs, taxes, regulations,etc.).

The model is estimated with the two–step Bajari, Benkard, and Levin (2007) estimation method for dynamic models of imperfect competition. The first stage of this method consists of estimating the optimal loan/deposit quantity and entry/exit choices period by period. The second stage then relies on these estimates to simulate the value of banks' optimal actions forward, as well as the values of alternate policy paths. Setting up inequalities using these simulated policy functions makes possible the estimation of the unknown structural parameters. These estimable parameters are country–specific fixed entry costs and scrap values, and the weights that capital regulators assign to the risk on bank portfolios. In addition, an estimate of banks' constant risk aversion parameter is obtained.

The estimation uses U.S. regulatory data spanning 3 bank size categories, 33 time periods between 1997 Q4 and 2005 Q4, and 46 countries. The estimation results for the policy functions (corresponding to the first step) show that controlling for selection bias in lending choices is important: banks lend on average 32.98 percent more to selected markets compared to a random sample of markets (corresponding to a correlation coefficient of 0.31 between the market presence and loan/deposit quantity equations). Selection causes upward bias in the coefficient estimates of over 12 percent. Furthermore, bank size (defined as total assets) and bank scope (defined as the lagged Sharpe ratio) have strong explanatory power in U.S. banks' foreign lending behavior, while market characteristics appear much less important. Scope has a stronger impact relative to size: results show that bank scope's effect is over three times as large as the size effect in the market entry and exit, as well as the loan and deposit quantity choices. In addition, cross–border loans and affiliate loans are shown to have very different sensitivities to bank and market traits — underlining the importance of examining them separately.

Estimation of the unknown structural parameters (corresponding to the second stage of the estimation) yields strongly significant estimates for the entry costs, scrap values and risk aversion parameters. In order to avoid estimates that depend on the *scale* of banks' operations in each country, banks' net interest income is adjusted for the scale–dependent operating costs (including branch network expenses). Simulated estimation results show that banks' constant, common absolute risk aversion parameter λ is 0.34 — somewhat higher than the previously estimated risk aversion parameters (e.g. Nishiyama 2007). Furthermore, estimates of regulators' risk aversion parameters vary greatly across countries. Bank regulators are generally more risk averse than banks, with an average risk aversion parameter of 0.52.

Correlations show that there is a strong positive relationship between estimates of entry costs and scrap values — indicating that countries which are more costly to enter also offer the possibility of greater scrap values. Correlation of the parameter estimates with empirical measures of location, economic strength and regulatory strictness (such as risk ratings, etc) reveals strong patterns. In particular, estimated entry costs appear higher in foreign markets that are inefficient, have greater government ownership in banks and are more profitable. Entry costs appear significantly higher in the Eastern European coun-

Table 2.6: Effects of Changes in Risk Aversion from 0.001 to 4 (Percent).

Change in Risk Aversion	Global Opers. Value	U.S. Opers. Value	Avg Fgn Opers. Value	Estim Entry Costs	Estim Scrap Value	Fgn Assets Share	Aff/CB Loan Ratio
Bank's	−12	−5.1	−5	23	65	15.1	−1.5
Foreign Regulator	1.3	1.9	−3.6	−1.2	−2.5	−21.4	−40.3
U.S. Regulator	−5.5	−8.2	7.9	−3	−8.7	38	−0.001

tries, and above average in Asian economies. Estimated regulatory risk aversions are higher in inefficient markets with stricter, but less effective, bank regulatory environments.

Simulation exercises are conducted to examine the effects on banks' optimal behavior of perturbing the bank risk aversion parameter, all foreign countries' risk aversions, and the U.S. regulator's risk aversion. These simulation exercises measure the effects of the perturbations on the overall value of banks' global operations; the value of U.S. operations, as well as the value of the average foreign country operation; the share of foreign assets in banks' portfolio, and the ratio of affiliate loans to cross–border loans. Table 2.6 summarizes the results of these simulation exercises.

CHAPTER 3

BRANCH NETWORK AND INTEREST RATE CHOICES OF HUNGARIAN COMMERCIAL BANKS

3.1 Introduction

Numerous studies and bank surveys (Bancography, 2003; Spieker, 2004) show that branch networks are an important strategic tool of commercial banks, in addition to the choices of interest rates. While building new branches is a powerful method of expanding market share, doing so is also very expensive. Surveys measured the fixed setup cost of a new branch to range from 1 million U.S. Dollars (Sheffield, 2006) to upward of 2 million U.S. Dollars (Spieker, 2004) in the U.S., which does not even include associated operating expenditures (Bancography, 2003). [1]. In light of the non–trivial benefits of branch network expansion, the purpose of this chapter is to examine imperfectly competitive Hungarian commercial banks's strategic choices of interest rates and branch network size in a dynamic setting. The chapter formulates a comprehensive model of bank behavior that captures branch network competition. Using bank–level Hungarian commercial banking data, the determinants of interest rate and branch network size choices, as well as the fixed branch setup costs and scrap values are estimated based on the modeling framework.

Branch network decisions are very closely tied to client location and socioeconomic status. Looking at the U.S. commercial banking market, surveys of the Federal Reserve Board suggest that the single most important factor influencing

[1] In the case of U.S. commercial banks, it has been documented that average total costs actually increase with branch network size (Spieker, 2004)

customers' choice of banks is the location of bank's branches (Governor Mark W. Olson, 2004). Furthermore, MarkeTech International assessed that traits related to location may account for 45 to 55 percent of deposit formation (Hopson and Rymers, 2003). Banks indeed take account of these factors in their branching decisions: per capita income and population density have been shown to be significant drivers of branch network expansion. These observations on bank and client behavior are the motivation behind this chapter's modeling of commercial bank branch network size choice as a game of spatial competition.

This chapter presents a dynamic Salop–style spatial competition model of profit maximizing commercial banks. Banks participate in retail and corporate banking markets. In the retail banking market, banks make loans in a variety of currencies, and compete in lending, mortgage and deposit rates, as well as their branch network size. Banks derive market power from the *location* of their branches, which they can influence by expanding or contracting their branch network. The corporate banking market is modeled as perfectly competitive, motivated by the discussions of Hungarian commercial banking in Molnár, Horváth, and Nagy (2007) and Móré and Nagy (2004). Therefore, banks take the corporate lending rates of all currencies as given.

Banks' dynamic profit maximization problem consists of two types of decisions. On one hand, banks make interest rate choices period by period. Interest rate choices only influence current profits and are therefore static.[2] On the other hand, banks choose the size of their branch network. Branch setup and closing decisions have–long term consequences, as the resulting branch network size will impact market share and interest rate choices for periods to come. In this

[2]That is, banks reassess the interest rates they charge on loans and pay on deposits each period.

chapter's modeling of branch opening and closing decisions, banks take these long–term consequences into account.

A version of the Bajari, Benkard, and Levin (2007) simulation–based estimation method is fitted to the framework of the theoretical model. Banks' optimal choices are estimated in two stages. The first stage examines the impact of current state variables (such as competitors' branch network size, consumer income, etc.) on banks' choices of interest rates. This stage also yields estimates of the determinants of banks' choices of how many new branches to open or close (constituting the transition probabilities for branch network size). Results show that banks charge a premium for greater branch network size in their lending rates, and offer lower deposit rates accordingly. Furthermore, greater branch network size of competitors induces banks to ask lower rates on loans, and offer higher deposit rates. A similar competitive pattern is observed in the branch network expansion and contraction choices: more branches of competitors make banks more likely to expand. Furthermore, banks with bigger branch networks are less likely to add new branches.

The second stage of the estimation uses the first–stage policy function estimates to construct banks' discounted expected sum of profits via forward simulation. Using the structure fitted to bank behavior, the values of numerous alternate policy paths are simulated. Estimates of branch setup costs and scrap values are then chosen to ensure that banks' observed (optimal) actions yield the highest bank value. Monthly estimates of branch setup costs show that with an average cost of 148.81 million HUF (approximately 0.75 million USD), setting up branches is considerably cheaper in Hungary than the U.S.[3]. With a mean of 109.48 million HUF, scrap values are approximately 75 percent of setup

[3]Much of this difference is likely be explained by deviations from price parity

costs. Setup costs and scrap values are very strongly positively correlated. Furthermore, they move closely with producer price indices capturing the cost of manufacturing and construction. Various simulation exercises are presented following the estimation, confirming the important role of branch network competition in bank behavior.

The chapter proceeds as follows. Subsection 3.1.1 provides an overview of Hungarian commercial banks' behavior during the sample period of January 2004 to November 2007. Section 3.2 motivates the modeling framework in the context of the related literature. Section 3.3 presents the model and characterizes banks' optimal behavior. Section 3.4 covers the estimation method and describes the data. Section 3.5 presents and discusses the estimation results, and Section 3.6 describes the simulation exercises. Section 3.7 summarizes and concludes the chapter.

3.1.1 Overview of the Hungarian Commercial Banking Market

The time period under examination in this paper is January 2004 to November 2007. During this time, the Hungarian retail banking sector is characterized by a high degree of market power, and active branch network expansion and contraction. The overview in this subsection focuses on two strategic tools of competition: choices of interest rates and branch network size.

An interesting and unique characteristic of the former Communist Central and Eastern European economies is the high share of foreign currency lending and deposit–taking relative to the local currency. During the period under examination, an average of 70 percent of Hungarian bank lending took place in foreign currencies, mostly in Euros (EUR), the Swiss Franc (CHF) and the Japanese Yen (YEN). Various foreign currencies appear within sub–types of loans (mortgages, retail, corporate), i.e. there is no specialization of loan types by currency.

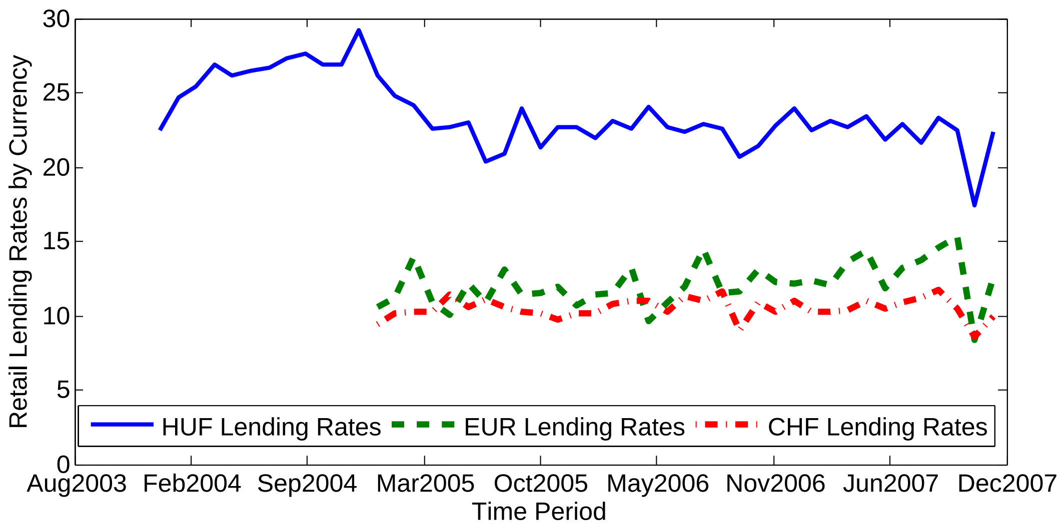

Figure 3.1: Average Retail Loan Rates by Currency Over Time.

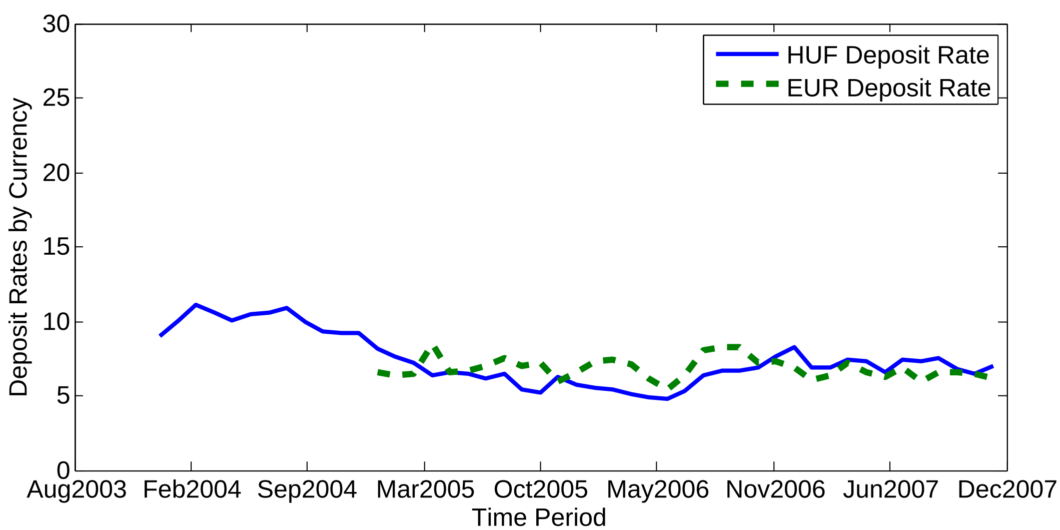

Figure 3.2: Average Retail Deposit Rates by Currency Over Time.

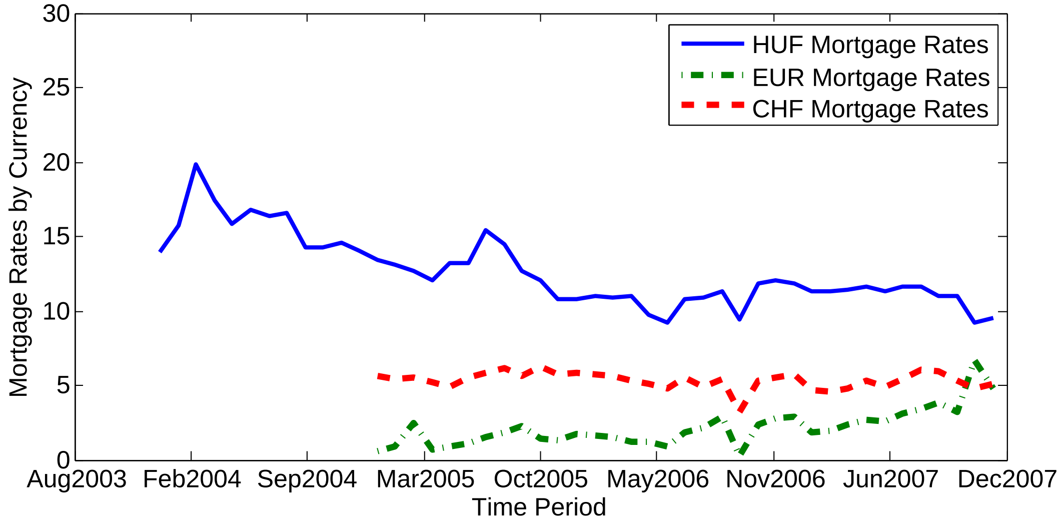

Figure 3.3: Average Mortgage Rates by Currency Over Time.

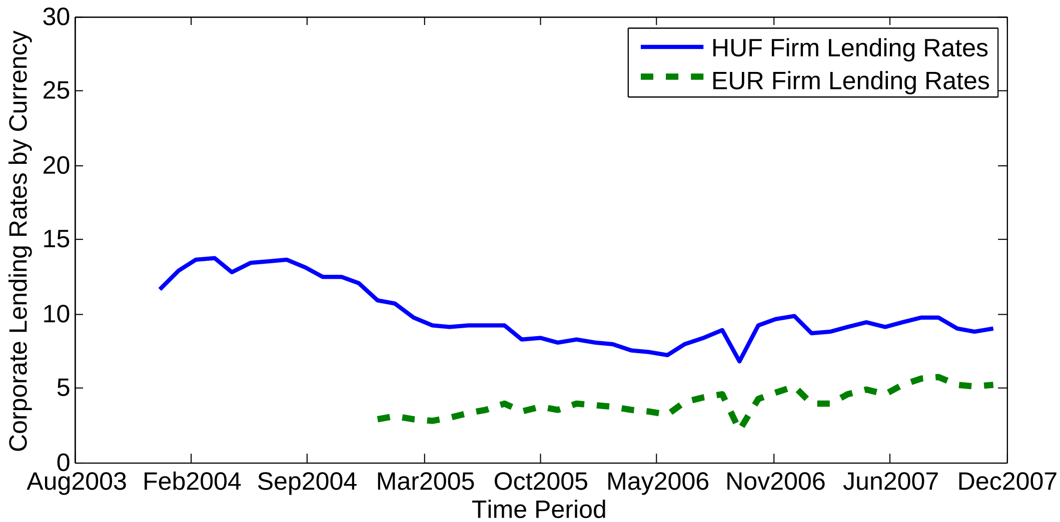

Figure 3.4: Average Corporate Lending Rates by Currency Over Time.

It is interesting to explore the reasons underlying the use of multiple currencies by banks: Ize and Yeyati (2003) show that risk averse banks are more prone to foreign currency holdings in the presence of lower exchange rate volatility and high price volatility. Pellényi and Bilek (2009) argue that both these factors were present in Hungary during the 2004–2007 period: inflation was relatively high compared to the EUR and CHF. At the same time, the Gyurcsany Administration promised to reduce exchange rate volatility by keeping the HUF fluctuations against the EUR within a 15 percent band (according to ERM-II). This latter action also contributed to the fact that consumers treated loans of various currencies as near perfect substitutes, vastly underestimating currency risk in pursuit of the significantly lower interest rates on foreign currency loans.[4]

Figures 3.1 and 3.3 and 3.4 show that the lending rates on different currency denominations vary widely. Most notable is the large spread between the retail lending rates on EUR and CHF loans, compared to the the HUF rate. Adjusting for expectations in currency appreciation (as well as inflation) does not explain away the large observed interest rate spreads between HUF and foreign currency–denominated loans.[5] The interest rate gap that remains between HUF and foreign currency loans after adjustments is large at around 10 percent. Persistent deviations from UIP have been well documented in the literature (Froot and Thaler, 1990). What might explain the empirical failure of UIP in the Hungarian case?

There is a clear and solid explanation for the low cost of foreign currency borrowing in Hungary. Basso, Calvo-Gonzales, and Jurgilas (2007) argue that banks which are headquartered abroad (characterizing the majority of Hungarian commercial banks) have easy access to foreign currency, at a low cost.[6] In the presence of monopolistic competition, they can use this advantage to compete for consumers via lower rates on foreign currency loans. Furthermore, it

[4]Pellényi and Bilek (2009) also present evidence that socioeconomic characteristics (such as education, income, etc.) fail to explain borrowers' choice of currency denominations.

[5]While Uncovered Interest Parity (UIP) does not explain the difference between HUF and foreign currency lending rates — as shown in Figure B.1 — it is in fact able to account for differences between observed EUR and CHF loan rates. It also explains differences in HUF and EUR deposit rates as shown by Figure B.2.

[6]Most foreign banks operating in Hungary are from Euro–zone countries. Therefore, the empirical fact that appreciation and inflation–adjusted EUR rates are consistently the lowest is in line with this argument on lower cost of foreign currency access.

has been argued that the very high cost of HUF borrowing is due to the uncertainty banks face in light of the unpredictable and imprudent fiscal policy of the Hungarian government (Ewing, May 6 2010). The time period under consideration between 2004 and 2007 was indeed characterized by a lot of uncertainty about fiscal policy, culminating in Prime Minister Gyurcsany's admission (on September 18, 2006) of having lied about fiscal actions and outcomes for several consecutive years (Condon, September 19 2006).

In light of the apparent gap between HUF and foreign currency borrowing rates, it is important to address the issue of arbitrage. For banks, the arbitrage opportunity would be to borrow from their Euro–zone parents at a low rate, change foreign currency into HUF, and make HUF loans at the higher rate. However, the lack of demand for loans at high rates greatly limits this opportunity. From consumers' perspective, the arbitrage opportunity would be to take out EUR and CHF loans at low rates, then re–lend the money at the higher rates after conversion into HUF. However, this opportunity is again limited by the apparent and persistent lack of demand for HUF loans at the high rates (Holland, Cochrane, and Penz, October 30 2008).

An important goal of this chapter is to address the role of branch networks in competition. Branch network size is an important source of market power in Hungary. According to Cottarelli (1998), "[the persistent market power of commercial banks is] largely reflecting their continued branch monopoly in regions of the country. The factor behind the continued dominance of these banks is the relatively high cost of establishing a branch network". It is indeed proof of the continued use of branch networks as a strategic tool that the time period under examination is very active in terms of branch network expansion and contraction. Figure 3.5 documents a steady sharp increase in the per–bank branch network size throughout the sample period. Figure 3.6 shows that the month–on–month branch network size change ranges from (−6) to (6) branches. The most common choices for the change in network size were closing 1 branch, keeping branch network size constant, and opening 1 branch.

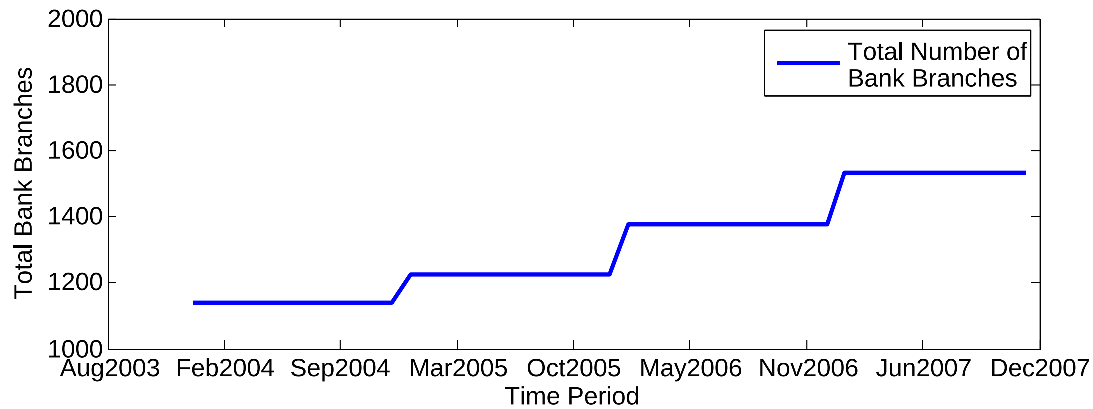

Figure 3.5: Average Branch Network Size Over Time.

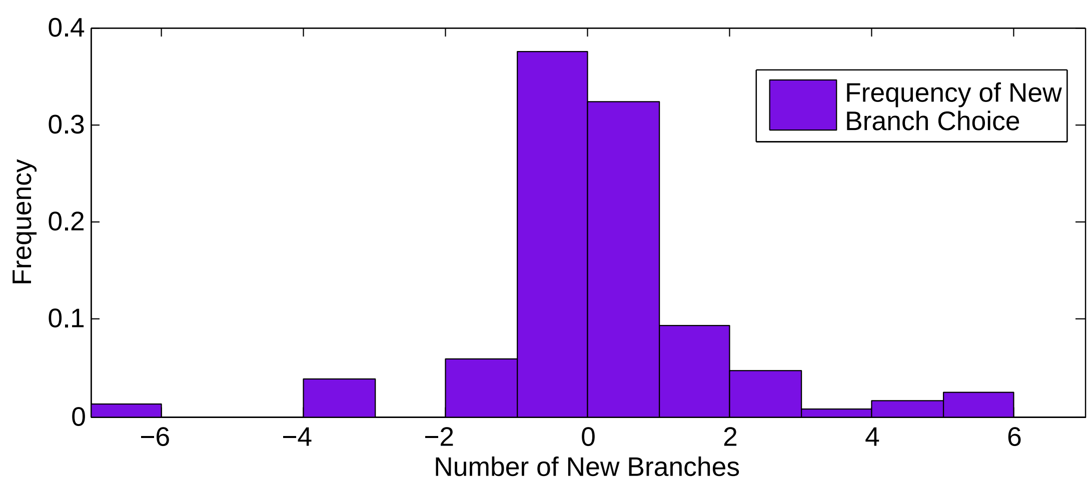

Figure 3.6: Frequency of Branch Network Size Expansion.

3.2 Motivation and Related Literature

This section gives summaries of the three strands of relevant literature. These strands are: (1) modeling imperfect and spatial competition in commercial banking; (2) dynamic estimation techniques for models of imperfect competition, and (3) evolution of Hungarian commercial banking.

3.2.1 Commercial Bank Competition

There have been numerous, mostly empirical papers, addressing spatial (branch network) competition in commercial banking markets. Most of the previous studies have focused on only one of the areas of deposit rate, lending rate or branch network competition. As an early example, Barros (1999) develops a spatial competition model to explain price differences across banks in the deposit market. His model separates two sources of market power: collusion in banking services, and location (taking branch networks as given). The paper examines whether banks' profitability is a result of conduct or market structure (location). He finds that location–based market power is the more important explanation for high margins in deposits. The applicability of Barros' work to the current framework is limited in that (1) he takes loan markets and branch networks as given — examining deposit rates as the only strategic tool, and (2) he abstracts away from any dynamic considerations.

Dell'Ariccia (2001) paints a more complete picture of strategic bank behavior by presenting a multi–period model of spatial competition, where banks' entry/exit decisions are endogenously determined. The paper shows that under asymmetric information and learning by lending, in equilibrium there is a finite number of competitors even in the absence of exogenous fixed costs. Even though the theoretical model (a multi–period extension of the Salop spatial competition model) is similar to the one presented in this chapter, Dell'Ariccia excludes branch banking as a strategic decision (the strategic choice of banks is whether to exist or not).

The work of Calem and Nakamura (1998) is one step closer to the framework of this chapter in that they explicitly include branch network competition. They build a model to show that branch banking broadens the geographic scope of competition among banks, and that banking services at peripheral locations will be priced more competitively when those locales are served by branch networks. Their theoretical model contains a central location with multiple banking outlets, and outlying locations with few banking outlets. Calem and Nakamura find that branching restrictions are associated with larger price differentials across banks. While their paper depicts branch banking, their main focus is to model a Bertrand pricing game between two banks that are competitors at the central location, but also have outlying branches.

Another step closer to the formulation of this chapter is Chiappori, Perez-Castrillo, and Verdier (1995). They analyze a spatial competition model of the banking sector, where banks offer loan and deposit services — though in a static setting. The goal of their paper is to investigate the consequences of the regulation of rates paid on deposits. The authors find that regulation first increases network size beyond social optimum, and in the long run result in lower equilibrium credit rates because of increased competition. They also show that regulation leads to tied services — as a result, an upper limit on deposit rates also restricts lending rates. They consider a one–period imperfect price competition model. The paper also incorporates spatial competition in the Salop framework. The applicability of their approach to this chapter is limited in that the authors exclude multi–branch banking by considering each branch to be an independent entity.

Kim and Vale (2001) build a bank branching model, where they consider the role of the size of the branch network in the provision of loans. The authors estimate a model of branching decisions where banks explicitly take account of both their own existing network and their expectation of rivals' choices. The paper tests whether there exist external informational spill–overs among banks due to branch network proliferation. They want to see whether branch networks have a market size effect, or only a market share effect. The paper sets up a non–price oligopolistic model of bank behavior in the loan market. The authors derive and estimate a simultaneous equations system of bank–level optimization rules for branching choice and loan equations. The predictions of the model are tested on Norwegian bank–level panel data. The paper's multi–period spatial competition model is relevant for this chapter, since it explicitly incorporates bank branching choices. However, in their model there is no price (interest rate) competition — banks treat loan quantities as their choice variable instead.

Estrada and Rozo's (2006) model incorporates competition in interest rates as well. They present a multi–market spatial competition oligopoly structure for the Colombian deposit market. In their model, banks use price and non–price strategies to compete in two periods. In the first period, banks choose the optimal loan and deposit rates for the whole country, according to Bertrand competition. In the second period, banks select the number of branches they plan to open in each region, given the optimal interest rates. While the strategic variables and the multi–period setup is relevant, their two–step optimization approach diverges from this chapter's goal. This is because the current chapter aims to model banks' lending and deposit rate, as well as bank network size choices simultaneously.

The modeling approach presented in this chapter is in agreement with that of Cerasi, Chizzolini, and Ivaldi (2002), who argue that branch network and price competition are closely tied together, and must be simultaneously modeled. They do this using a static non–cooperative two–stage game, where branching decisions are taken in the first stage, and monopolistically competitive interest rates are set in the second stage. The authors derive structural equations in order to measure branching costs and degree of competition in banking services, and fit the model's equations to bank–level European panel data.

Closest to this chapter is the work of Kim, Lozano-Vivas, and Morales (2007), who present a multi–strategic, multi–market and multi–output oligopolistic spatial model of a monopolistically competitive banking sector. In their model, banks take explicit account of the impact of their strategies on their existing branch network and market share, as well as the reaction of their competitors. The three strategic variables of each bank are: deposit interest rates, loan interest rates and the number of branches in a given region. Kim, Vivas and Morales present a static model, whose parameters are estimated using Spanish data. This chapter takes a similar modeling framework and extends it to a more realistic dynamic setting.

A closely related paper by Berger and Mester (2003) examines the relationship between commercial bank efficiency and branch network size. They find that greater branch network size does not provide cost efficiencies — but there are indeed revenue improvements. The authors explain banks' continued drive to expand their branch network size and improve services by the assertion that the corresponding growth in revenues outpaces cost increases.

An important part of this chapter's analysis is to account for how consumers respond to changes in the attributes of banking services (albeit in a spatial competition framework). This approach is motivated by Dick (2007), who estimates the demand for deposit services in the U.S. commercial banking industry. Her goal is to assess the effect on consumers of the significant changes in banking services throughout the 1990s. Dick's model accommodates the various changes that have taken place in banking markets, as well as the elimination of branching restrictions on U.S. banks. The author estimates a multinomial discrete choice nested logit model of demand. This is a structural model which incorporates product differentiation. The results show that consumers respond to various bank attributes, beyond prices. The results also suggest that consumers have benefited from nationwide branching in the United States.

3.2.2 Estimation Method

The main contribution of this chapter compared to previous literature is the presentation of spatial bank competition in a dynamic framework. Taking account of dynamics is especially important when looking at branch network competition, where branch building and closing decisions have consequences that last well beyond a single period. However, solving a full–fledged dynamic optimization problem has a very high computational cost. The problem is made tractable by formulating a version of the Bajari, Benkard, and Levin (2007) two–step estimation method (motivated by Hotz and Miller (1993)) for the current framework.

The first stage of the two–step estimation consists of a reduced–form regression of banks' policy functions on all the current state variables. Using these estimates, it is possible to get a form of banks' discounted sum of expected profits as functions of the state variables and the model's structural parameters only. Furthermore, data can be used to estimate the transition probabilities of all the relevant state variables. The second stage consists of forward simulation of the values of bank's optimal choices. Best estimates of the structural parameters are then chosen to ensure the optimality of observed actions compared to any other sub–optimal policy paths. Further relevant papers — discussing estimation methods which avoid solving the full–blown dynamic optimization problem — are Ericson and Pakes (1995), Berry, Levinsohn, and Pakes (1995), Olley and Pakes (1996) and Pakes, Ostrovsky, and Berry. (2007).

3.2.3 Evolution of Hungarian Commercial Banking

There have been numerous papers examining the conditions of the Hungarian commercial retail banking market starting with the first years of privatization in the early 1990s (Ábel and Bonin, 2000; Ábel and Siklos, 2004; Király and Várhegyi, 2004; Majnoni, Shankar, and Várhegyi, 2003). Notably, Várhegyi (2004) describes the competitive evolution of the Hungarian banking sector. She examines bank competition in Hungary using a structural approach. This approach assumes that the best way to influence competition is by affecting the market structure. The study first examines bank competition in Hungary since 1990, and then uses behavioral models to describe bank competition in the period 1995–2002. The paper argues that during this period, banks had a price–setting role in loan markets, and a price–accepting role in deposit markets. The author uses various empirical I.O. models to test market structure and market power. The modeling formulation of this chapter is partly motivated by the following findings of Várhegyi (2004): (1) while the corporate loan market is competitive, the retail market is still characterized by considerable market power of banks, and (2) price competition is the best description of strategic choices in the Hungarian banking market — while collusion can be ruled out.

In a related paper, Móré and Nagy (2004) investigate the degree of bank competition in Hungary in various sub–markets. The authors conjecture that there is a high degree of market power in consumer lending, and that competitive pricing prevails in the corporate lending market (in line with Várhegyi (2004)). Móré and Nagy (2004) use a non–structural model of competition to test their hypotheses of competition, using bank–level panel data. After estimating conjectural variation for each sub–market, they show that the degree of competition in both the loan and deposit markets falls between perfect competition and the Cournot equilibrium. The consumer credit sub–market, however, is characterized by a much lower degree of competition: between Cournot equilibrium and perfect collusion. Low level of competition and inelastic demand allows banks to receive large oligopolistic rents in the consumer credit sub–market. Estimating the loss of consumer surplus resulting from imperfect competition, the authors find these losses to be small.

The model of this chapter is informed by Molnár, Horváth, and Nagy (2007), who build a structural model of the Hungarian retail banking industry. In this static model, the authors estimate residual demand and supply functions of household loan and deposit services. For the supply side, the authors consider two models of the banking industry: a static, differentiated–product Nash–Bertrand oligopoly and a cartel. For each supply model, the pricing decisions of the bank depend on the individual bank–level demands. The authors estimate a discrete choice multinomial logit model of demand for consumers' loan demand and deposit services. The results show that the observed price–cost margins are very high for overdrafts, higher purchase loans, personal loans and demand deposits, and lower for short–term and long–term deposits. In order to identify the structure of competition, the authors compare the estimated price–cost margins implied by the Nash–Bertrand and cartel models to the observed values. The results suggest that in the overdraft, hire purchase loan, personal loan, demand deposit, and short–term deposit markets, the degree of competition is low. Long-term deposit markets can be characterized as fairly competitive. When the authors control for consumer default risks and inflation, the observed margins are even closer to competitive values.

3.3 Model

This section describes the theoretical modeling framework. The economy consists of households, firms and commercial banks. There is a large number of utility–maximizing households. The corporate sector consists of a fixed number of profit–maximizing firms $f = 1 \dots F$. There is a total number of T periods, with t indexing the individual period. The time subscript is suppressed throughout the description of the model. There are a total of J commercial banks in the economy, with $j = 1 \dots J$ indexing the individual bank. Commercial banks provide deposit and loan services to retail customers, and loan services to corporate customers. Banks' goal is to maximize the discounted sum of expected profits over time. They do so by choosing lending rates, deposit rates and their branch network size in the retail sector. Banks choose their optimal lending rates in the corporate sector (where there is no spatial competition, and network size plays no role).

The economy consists of a single location, which has a circular shape in accordance with the Salop spatial competition model as described in Salop (1979) and Freixas and Rochet (2008). The circular economy has circumference A. Each bank j has one headquarter, and a number n of bank branches, denoted by n_j. Then the total number of branches in the economy is $N = \sum_j n_j$. Bank branches are uniformly distributed along the Salop circle, so that the distance between each branch is $\frac{A}{N}$. Households are also uniformly distributed along the Salop circle, with a total mass of A. As banks increase their branch network size, N changes over time. However, A changes at the same rate as N, so that the ratio A/N (and hence the location of each existing branch) is independent of new branching decisions. Figure 3.7 describes the locational structure of the model.

3.3.1 Retail Sector — Households

Households live for two periods, and consume the single consumption good c in each period. Households form overlapping generations, so that some households are in their first period of life, while others are in their second (last) period

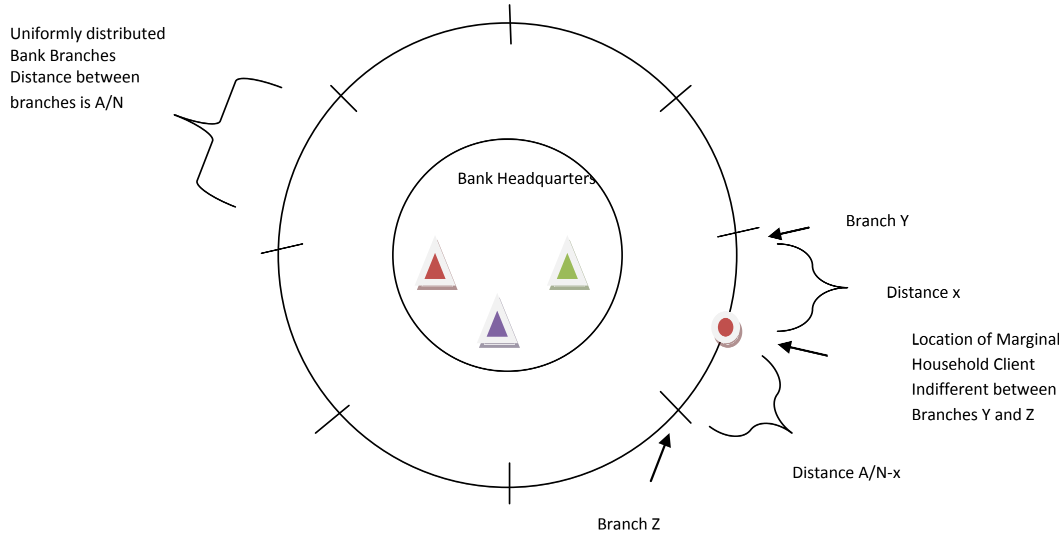

Figure 3.7: Illustration of Model Structure.

of life in each period t. Given their income I, each household's goal is to choose consumption c_t so as to maximize the sum of its discounted expected utility over the two periods of its lifetime. Households are identical except for their discount factor β^h, which defines each household's 'type'. The discount factor is known and is drawn from a uniform distribution $U[0, 1]$. This distribution is constant over time, and the β^h draws are independent across periods.

Households can save (and deposit at the bank) some of their income in the first period of their life, that is, when they are young. A negative saving $s^h < 0$ implies borrowing. Households deposit their saving and obtain their borrowing at the nearest bank branch along the circle. The nearest branch charges rate r_l^h on loans and pays rate r_d^h on deposits.

The retail banking market (both lending and deposit–taking) is monopolistically competitive. This is because households are constrained by their location, and can only choose between the two nearest branches. This serves as a source of market power for banks. Each household takes $\left(I; \beta^h; r_d^h; r_l^h\right)$ as given. Let x

denote the distance between the household and the nearest branch, which the consumer must travel to access banking services. Then each household's goal is to choose the stream of consumptions $C = \left(c_1^h, c_2^h\right)$ so as to maximize its discounted lifetime sum of logarithmic utilities as follows.

$$\max_C \log\left(c_1^h\right) + \beta^h \cdot \log\left(c_2^h\right) - \left(1+\beta^h\right) \cdot \log(x) \tag{3.1}$$

subject to

$$\begin{aligned} c_1^h &\leq I - s^h \\ c_2^h &\leq I + \left(1 + r_l^h\right) \cdot \min\left\{s^h, 0\right\} + \left(1 + r_d^h\right) \cdot \max\left\{s^h, 0\right\} \end{aligned} \tag{3.2}$$

There are two types of young people in each period: borrowers (with $s^h < 0$) and depositors (with $s^h > 0$). Young household type depends on the discount factor β^h. Furthermore, households form expectations of next period's income such that $E(I') = I$.

Let $l^h = s^h$ if $s^h < 0$. Solving for depositors and borrowers separately, we get

$$\begin{aligned} s^{h*} &= \left[\frac{\beta^h\left(1 + r_d^h\right) - 1}{\left(1 + r_d^h\right)(1+\beta^h)}\right] I \\ c_1^{h*} &= \left[\frac{\left(2 + r_d^h\right)}{(1+\beta^h)\left(1 + r_d^h\right)}\right] I \\ c_2^{h*} &= \left[\frac{\left(2 + r_d^h\right)\beta^h}{(1+\beta^h)}\right] I \end{aligned} \tag{3.3}$$

for depositors. The corresponding solution for borrowers is

$$\begin{aligned} l^{h*} &= \left[\frac{1 - \beta^h\left(1 + r_l^h\right)}{\left(1 + r_l^h\right)(1+\beta^h)}\right] I \\ c_1^{h*} &= \left[\frac{\left(2 + r_l^h\right)}{(1+\beta^h)\left(1 + r_l^h\right)}\right] I \\ c_2^{h*} &= \left[\frac{\left(2 + r_l^h\right)\beta^h}{(1+\beta^h)}\right] I \end{aligned} \tag{3.4}$$

It follows that the effect of β^h on whether the household is a depositor or borrower is as follows:

$$\begin{aligned} &\text{Depositor if} && \frac{1}{1+r_d^h} < \beta^h \\ &\text{No banking if} && \frac{1}{1+r_l^h} < \beta^h < \frac{1}{1+r_d^h} \\ &\text{Borrower if} && \beta^h < \frac{1}{1+r_l^h} \end{aligned} \tag{3.5}$$

Given the known uniform distribution of β^h and the total mass of consumers A, we can integrate over the ranges defined in (3.5) to get the approximate market supply of deposits and market demand for loans as follows.

$$\begin{aligned} &\text{Deposit Supply:} \\ &D^h = \int_{\left(1+r_d^h\right)^{-1}}^{1} \left(s^h\right)^* d\beta^h \cdot A = \left(3.2r_d^h + 0.4 + r_d^{h2}\right) \cdot I \cdot A \\ &\text{Loan Demand:} \\ &L^h = \int_{0}^{\left(1+r_l^h\right)^{-1}} \left(l^h\right)^* d\beta^h \cdot A = \left(1 - 1.5r_l^h - r_l^{h2}\right) \cdot I \cdot A \end{aligned} \tag{3.6}$$

Banks observe the market supply of deposits and the market demand for loans. Substitution of the optimal solutions from Equations (3.3) and (3.4) yields the young household's lifetime indirect utility V^h. Letting subscript $m = (d, l)$ for deposits and loans, this indirect utility is given by

$$\begin{aligned} V^h\left(\beta^h, I, x, r_m^h\right) &= u\left(c_1^h\right)^* + \beta^h \cdot u\left(c_2^h\right)^* - \left(1+\beta^h\right) \cdot \log(x) = \\ &\log\left\{\frac{\left(2+r_m^h\right) \cdot I}{(1+\beta^h)(1+r_m^h)}\right\} + \beta^h \cdot \log\left\{\frac{\beta^h \cdot \left(2+r_m^h\right) \cdot I}{1+\beta^h}\right\} - \left(1+\beta^h\right) \cdot \log(x) \end{aligned} \tag{3.7}$$

Given that households are uniformly distributed along the Salop circle, they can choose to bank at either of the two nearest bank branches, depending on the offered interest rates r_m^h and the distance x. Let j and $j+1$ index two branches owned by bank j and $j+1$, respectively. The location of the marginal household is characterized by the critical value of x, denoted by $\bar{x}$, such that the household is indifferent between going to branch j and branch $j+1$. Let r_j^h and r_{j+1}^h denote the rates offered at branches j and $j+1$, respectively. Using a first–order Taylor expansion and (3.7), the approximate location of the marginal household is[7]

$$\bar{x} = \frac{A \cdot \left(2 + \left(r_j^h - r_{j+1}^h\right) \cdot \left(\beta^h \cdot \left(1 + r_j^h\right) - 1\right)\right)}{4N \cdot (1 + \beta^h)} \tag{3.8}$$

From (3.8) it follows that a higher $\bar{x}$ means more customers for branch j. Therefore, (3.8) implies that branch j's borrower customer base shrinks with higher lending rates, and its depositor base increases in higher rates. Similarly, higher lending rates of competitors increase branch j's client base, while higher deposit rates of competitors mean fewer depositors at branch j[8]. Furthermore, $r_j^h = r_{j+1}^h$ implies that the marginal client is halfway between the two nearest branches. Banks observe the location of the marginal household, and take $\bar{x}$ into account in their deposit/lending rate and branch network size decisions. In the following analysis, the values of β are fixed such that $\beta^h = 0$ for those who borrow, and $\beta^h = 1$ for depositors.

3.3.2 Firms

There are F firms in the economy, with subscript f denoting the individual firm. Firms are owned by shareholders, who provide starting capital b in each period. Shareholders' goal is to maximize profits over the course of two periods. Profits are distributed to shareholders at the end of the second period. Each firm produces a single good y_t that is identical across all firms. Let superscript c denote

[7]This critical value $\bar{x}$ is obtained by solving $V\left(\beta^h, I, \bar{x}, r_j^h\right) = V\left(\beta^h, I, \left(\frac{A}{N} - \bar{x}\right), r_{j+1}^h\right)$.

[8]This follows directly from the characterization described in (3.5).

corporate. Capital $K = \left(k_1^c; k_2^c\right)$ is the only input in the production of the identical good. The production function is concave and given by $y = f(k^c)$. The production technology is identical across all firms and over time.

Banks lend to firms in *perfectly competitive* loan markets. Each firm can obtain corporate loan l^c from banks at the perfectly competitive corporate lending rate r_l^c. Corporate loan l^c borrowed in the first period must be repaid in the second period. Firms sell their output to households for consumption. Households pay a price of one (unity) for the output in both periods of the firm's life. Let β^c denote the firm's known discount factor, whose uniform distribution $U[0,1]$ is constant over time (with the β^c draws also independent over time). Then firm f's two–period profit-maximization problem is to choose $K = \left(k_1^c; k_2^c\right)$ so as to

$$\max_K \sqrt{k_1^c} + \beta^c \cdot \sqrt{k_2^c}$$
$$\text{subject to} \quad \begin{array}{l} k_1^c \leq b + l^c \\ k_2^c \leq b - (1 + r_l^c) \cdot l^c \end{array} \tag{3.9}$$

The corresponding optimal solutions are

$$\begin{aligned} (k_1^c)^* &= \frac{\left(2 + r_l^c\right) \cdot b}{\left(1 + r_l^c\right)\left(1 + \beta^{c2}\left(1 + r_l^c\right)\right)} \\ (k_2^c)^* &= \frac{\beta^{c2}\left(1 + r_l^c\right)\left(2 + r_l^c\right) \cdot b}{1 + \beta^{c2}\left(1 + r_l^c\right)} \\ l_{ct}^* &= \frac{\left(1 - \beta^{c2}\left(1 + r_l^c\right)^2\right) \cdot b}{\left(1 + r_l^c\right)\left(1 + \beta^{c2}\left(1 + r_l^c\right)\right)} \end{aligned} \tag{3.10}$$

It follows that each firm borrows a non–negative amount only if its discount factor β^c is sufficiently low, i.e. if $\beta^c \leq \left(1 + r_l^c\right)^{-1}$. Since there are F identical firms in the economy, firms' market demand function for bank loans is given by

$$(L^c)^* = \frac{\left(1 - \beta^{c2}\left(1 + r_l^c\right)\right) \cdot F \cdot b}{\left(1 + r_l^c\right)\left(1 + \beta^{c2}\left(1 + r_l^c\right)\right)} \tag{3.11}$$

Each bank observes this market demand function for loans.

3.3.3 Banks

Bank Services to Households

Each bank j provides lending and deposit services to households after choosing its optimal retail lending rate $\left(r_{lj}^h\right)^*$, retail deposit rate $\left(r_{dj}^h\right)^*$ and branch network size $\left(n_j\right)^*$. Recall that each bank can operate multiple branches. Suppose bank j operates the j'th branch. The quantities of deposits supplied and loans demanded depend on whether the neighboring branches — denoted by $j-1$ and $j+1$ — belong the bank j or not. Given the characterization in (3.8) of the location of the marginal household, the *expected* volume of loans and deposits attracted by bank j is

$$\begin{aligned} E\left(L_j^h\right) = n_j \cdot \Bigg\{ \frac{L^h}{4} \cdot \frac{A}{N} \cdot \Big[& \mathrm{Prob}\left(j-1 = j\right) \cdot \mathrm{Prob}\left(j+1 = j\right) \cdot (4) \\ & + \mathrm{Prob}\left(j-1 \neq j\right) \cdot \mathrm{Prob}\left(j+1 \neq j\right) \cdot \left(4 + r_{lj+1}^h + r_{lj-1}^h - 2r_{lj}^h\right) \\ & + \mathrm{Prob}\left(j-1 = j\right) \cdot \mathrm{Prob}\left(j+1 \neq j\right) \cdot \left(4 + 2\left(2 + r_{lj+1}^h - r_{lj}^h\right)\right) \Big] \Bigg\} \end{aligned} \tag{3.12}$$

In (3.12), the first line within the curly brackets shows the expected branch–specific loan demand if both neighboring branches belong to bank j. The second line shows the expected demand if none of the neighboring branches belong to bank j. The last line shows the expected branch–level demand if only one of the neighboring branches belongs to bank j. The per–branch expected loan demand is then multiplied by the number of branches bank j owns. The similar expression for the quantity of deposits supplied that bank j expects to attract is:

$$\begin{aligned} E\left(D_j^h\right) = n_j \cdot \Bigg\{ \frac{A}{8N} \cdot \frac{D^h}{A} \cdot \Bigg[&\text{Prob}\,(j-1 = j) \cdot \text{Prob}\,(j+1 = j) \cdot (4) \\ &+ \text{Prob}\,(j-1 \neq j) \cdot \text{Prob}\,(j+1 \neq j) \cdot \left(4 + r_{dj}^h \cdot \left(2r_{dj}^h - r_{dj+1}^h - r_{dj-1}^h\right)\right) \\ &+ \text{Prob}\,(j-1 = j) \cdot \text{Prob}\,(j+1 \neq j) \cdot \left(8 + 2r_{dj}^h \cdot \left(r_{dj}^h - {}_{dj+1}^h\right)\right)\Bigg]\Bigg\} \end{aligned} \tag{3.13}$$

Note that Equations (3.12) and (3.13) are constant in the term $\frac{A}{N}$. This implies that new branches bring new customers, and the location of each existing branch is independent of new branching decisions. A further implication is that new branches do not cause consumers to regroup. Therefore, for given interest rates there are two ways branch network size n_j impacts the expected loan and deposit volumes of bank j. First, adding a new branch expands the loan and deposit volumes by the per–branch amounts shown in (3.12) and (3.13) in curly brackets. Second, n_j affects the probabilities that the neighboring branches also belong to bank j. The following subsections describe banks' optimal choices of the interest rates and branch network size.

3.3.4 Price Competition

Banks choose their interest rates period by period, in an imperfect competition setting. The interest rate choices are static because profits are redistributed to bank shareholders at the end of each period. Therefore, chosen interest rates influence current profits, but have no impact on future profits. Let $\Psi = \left(c_l^h; c_d^h; c_l^c\right)$ denote the proportional costs of household lending, deposit taking and corporate lending, respectively. Furthermore, ϕ is the required reserve ratio, $\tilde{r}$ denotes the interest paid on interbank loans and c_{nj} is the per–branch operational cost. In price competition, each bank's goal is to choose the optimal values of $R_j^* = \left(r_{lj}^{h*}; r_{dj}^{h*}; r_{lj}^{c*}\right)$ so as to maximize the price–relevant part of its profit function in each period, taking its network size n_j as given.

$$\max_{R_j} E\left(\pi_j\right) = \left(r_{lj}^h - \tilde{r} - c_{lj}^h\right) \cdot E\left(L_j^h\right) + \left(\tilde{r} \cdot (1-\phi) - r_{dj}^h - c_{dj}^h\right) \cdot E\left(D_j^h\right) + \left(r_{lj}^c - \tilde{r} - c_{lj}^c\right) \cdot L_j^c - c_{nj} \cdot n_j \quad (3.14)$$

Since the corporate sector is monopolistically competitive, the lending rate there is equal to the marginal cost of lending. Furthermore, the corporate market is equally divided among all banks lending to firms. The following first–order optimality conditions characterize the optimal choices of retail lending, retail deposit and corporate lending rates, respectively.

$$E\left(L_j^h\right) + \left(r_{lj}^h - \tilde{r} - c_{lj}^h\right) \cdot \frac{\partial E\left(L_j^h\right)}{\partial r_{lj}^h} = 0 \quad (3.15)$$

$$-E\left(D_j^h\right) + \left(\tilde{r} \cdot (1-\phi) - r_{dj}^h - c_{dj}^h\right) \cdot \frac{\partial E\left(D_j^h\right)}{\partial r_{dj}^h} = 0 \quad (3.16)$$

$$r_{lj}^c = c_{lj}^c + \tilde{r} \quad (3.17)$$

In this model there are multiple equilibria, so that the equilibrium characterized by (3.15) through (3.17) is not unique. In what follows, the equilibrium yielding the highest price (interest rate) is selected, in order to underline the role of market power and deviation from perfect competition. Recall that $N = \sum_j n_j$ denotes the total number of bank branches across all banks. Then let n_{-j} denote the total number of *competitors'* (other banks') branches. Expressions (3.15) through (3.17) imply the following comparative statics results:

$$\left\{\frac{\partial r_{lj}^{h*}}{\partial c_{lj}^{h}}; \frac{\partial r_{lj}^{h*}}{\partial \tilde{r}}; \frac{\partial r_{lj}^{h*}}{\partial n_j}; \frac{\partial r_{lj}^{h*}}{\partial I}\right\} > 0 \tag{3.18}$$

$$\left\{\frac{\partial r_{lj}^{h*}}{\partial n_{-j}};\right\} < 0 \tag{3.19}$$

$$\left\{\frac{\partial r_{dj}^{h*}}{\partial \tilde{r}}; \frac{\partial r_{dj}^{h*}}{\partial n_{-j}}; \frac{\partial r_{lj}^{c*}}{\partial c_{lj}^{c}}; \frac{\partial r_{lj}^{c*}}{\partial \tilde{r}}\right\} > 0 \tag{3.20}$$

$$\left\{\frac{\partial r_{dj}^{h*}}{\partial n_j}; \frac{\partial r_{dj}^{h*}}{\partial c_{dj}^{d}}; \frac{\partial r_{dj}^{h*}}{\partial \phi}; \frac{\partial r_{dj}^{h*}}{\partial I}\right\} < 0 \tag{3.21}$$

Let the variable cost vector Ψ evolve over time according to a discrete Markov process. Let Δ denote the discrete set of Ψ's. Let the monetary policy parameters $(\tilde{r}; \phi)$ evolve over time according to a discrete Markov process with Ω denoting their discrete set. Based on the symmetric price equilibrium described above, the value of each bank's variable profit function is:[9]

$$\begin{aligned} \pi_j^*\left(R_j^*; n_j; \Delta; \Omega\right) = \\ \left(r_{lj}^{h*} - \tilde{r} - c_{lj}^{h}\right) \cdot E\left(L_j^{h*}\right) + \left(\tilde{r} \cdot (1-\phi) - r_{dj}^{h*} - c_{dj}^{h}\right) \cdot E\left(D_j^{h*}\right) \\ + \left(r_{lj}^{c*} - \tilde{r} - c_{lj}^{c}\right) \cdot L_j^{c*} - c_{nj} \cdot n_j \end{aligned} \tag{3.22}$$

Equation (3.22)is used to analyze banks' optimal choice of branch network size in a dynamic setting.

3.3.5 Branch Network Choice

Banks simultaneously choose by how much to increase or decrease the size of their branch network. Let $a_j = n_j^{'} - n_j$ denote bank j's choice of network size

[9] Note that the variable profit function does not contain the fixed branch network expansion costs and scrap values.

expansion, such that $n_j + a_j = n'_j$ (note that $a_j < 0$ implies a reduction in bank j's branch network size). Banks choose a_j with the understanding that n'_j will affect their variable profits at future periods. Let $n = (n_1; ...; n_J)$ denote the vector of bank–specific network sizes at time t. Let $\Theta = (\Delta; \Omega)$ denote the set of known state variables. Then each bank's current *total* profit function is

$$\Pi_j (\Theta; n; \Xi; \epsilon) = \pi^*_j (\Theta; n) - F\left(a_j\right) - E\left(a_j\right) \tag{3.23}$$

In (3.23), $F\left(a_j\right)$ is the entry cost of opening a new branch and $E\left(a_j\right)$ is the scrap value of closing an existing branch. Both these values depend on bank–specific idiosyncratic shocks as follows:

$$\begin{aligned} F\left(a_j\right) &= f \cdot \left(a_j\right) + \epsilon_j \\ E\left(a_j\right) &= e \cdot \left(a_j\right) + \epsilon_j \end{aligned} \tag{3.24}$$

In (3.24), $\Xi = (f; e)$ are the estimable time–varying parameters. Let $\epsilon = (\epsilon_1; \ldots; \epsilon_J)$ denote the vector of idiosyncratic shocks of all banks. It is assumed that this vector is independent of the elements of Θ, and independently distributed across banks and over time. Independence across banks implies that a bank cannot learn about other banks' ϵ's by using its own private information. Independence over time means that a bank cannot use other banks' histories of previous decisions to infer their current shocks. It is also assumed that the ϵ's have support over the entire real line with a cumulative distribution increasing with respect to every argument.

The profit function in (3.23) depends on Ξ, and hence bank j's optimal choice of branch network size expansion a^*_j is also a function of the set of unknown structural parameters.

Markov Perfect Equilibrium

It is assumed that bank j's strategy depends only on its payoff–relevant state variables $(\Theta; n; \epsilon; \Xi)$. Let $\alpha \equiv \alpha(\Theta; n; \epsilon; \Xi)$ be a set of strategy functions, one for each bank, such that $\alpha : \{n\}^J \times \Theta \times R^2 \rightarrow A$ where $A = (a_1; \ldots; a_J)$. Let ψ_j denote each bank's value such that

$$\psi_j(\Theta; n; \epsilon; \alpha; \Xi) = E\left[\Pi_j\left(\Theta; n_j; \epsilon; a_j; \Xi\right) + \upsilon_j^\alpha\left(\Theta; n_j; a_j; \Xi\right)\right] \tag{3.25}$$

where υ_j^α is the expected future profits of each bank if its current decision is a_j and all the other banks, including itself, behave in the future according to their respective strategy functions in α. That is,

$$\upsilon_j^\alpha\left(\Theta; n_j; a_j; \Xi\right) = \sum_{s=1}^{\infty} \gamma^s E_s\left\{\Pi_{sj}\left[\Theta_s; \alpha_s\left(\Theta_s; n_s^\alpha; \epsilon_s\right), n_s^\alpha; \epsilon_s\right] \mid \Theta; a_j; n_j; \Xi\right\} \tag{3.26}$$

where the expectation is taken over all the possible future paths of $\{\Theta; \epsilon\}$. The super–index α is used in n_s^α to emphasize that the evolution of future networks of bank branches depends on the strategy functions in α. *A Markov Perfect Equilibrium (MPE)* in this game is a set of strategy functions α such that each bank's strategy maximizes the value of the bank for each possible $\left(\Theta; n_j; \epsilon; \Xi\right)$ and taking other banks' strategies as given. That is, α is a MPE if for all banks, states $\left(\Theta; n_j; \epsilon\right)$, structural parameters Ξ and Markov strategies α',

$$\psi_j\left(\Theta; n_j; \epsilon; \alpha; \Xi\right) \geq \psi_j\left(\Theta; n_j; \epsilon; \alpha'_j; \alpha_{-j}; \Xi\right) \tag{3.27}$$

Given (3.23) and (3.27), it is now possible to describe the form of bank j's branch network choices as follows:

Change branch network size by $a_j = m_j$ if, for $m_j \neq \tilde{m}_j$,

$$\begin{aligned}-F\left(m_j\right)\left(1 : m_j > 0\right) - E\left(m_j\right)\left(1 : m_j < 0\right) + \upsilon_j^\alpha\left(\Theta; a_j = m_j; n_j; \Xi\right) \\ \geq -F\left(\tilde{m}_j\right)\left(1 : \tilde{m}_j > 0\right) - E\left(\tilde{m}_j\right)\left(1 : \tilde{m}_j < 0\right) + \upsilon_j^\alpha\left(\Theta; a_j = \tilde{m}_j; n_j; \Xi\right)\end{aligned} \tag{3.28}$$

The expression in (3.28) indicates that expanding (or contracting, if $m_j < 0$) bank j's network size by m_j branches has greater value than choosing any other $\tilde{m}_j$. Similar to the static price competition equilibrium characterized in (3.15) through (3.17), this branch network size choice can also have multiple equilibria. Recall that in the price competition, the equilibrium yielding the highest price was selected, in order to underline the role of market power and deviation from perfect competition. In the dynamic network game, the selected equilibrium is the one that the model converges to by iterating from the initial set of values $\upsilon_j^{\alpha} = 0$ (which are the values corresponding to the $\gamma_j = 0$ case). It is important to emphasize again that from (3.28), the optimal network size choice depends on the set of unknown structural parameters in Ξ.

3.4 Estimation

The model's structural parameters of interest are the profit function, the discount factor γ, the transition probabilities, the distribution of bank–specific private shocks, the time–specific branch network expansion costs and scrap values. The form of the profit function is assumed to be linear, as described above. The constant discount factor γ is derived from lending rates over time. The distribution of bank–specific private shocks is assumed to be known. Therefore, the structural parameters that remain to be estimated are the transition probabilities, the fixed branch network expansion costs and the scrap values.

The estimation method follows the two–step procedure developed in Bajari, Benkard, and Levin (2007) along the lines of Hotz and Miller (1993). In the first stage, the optimal interest rates and the branch network expansion choices are estimated as functions of all the state variables. These first–stage estimates provide predictions for the policy functions[10].

Using the policy function predictions, each bank's value can be written as a function of the state variables and the unknown structural parameters only. The goal of the second stage of the estimation is to use these value functions to find the set of structural parameters that *rationalize* the observed policy choices compared to the values of multiple sub–optimal policy paths.

3.4.1 First Step: Policy Functions and Transition Probabilities

The goal of the first step of the estimation is to write each bank's discounted sum of profits in (3.25)) as functions of the state variables and structural parameters only. In order to do so, it is first important to establish a mapping between these variables and banks' policy choices. Second, empirical estimates of the transition probabilities of the exogenous state variables are needed.

The interest rate choices are estimated based on Equations (3.15) through (3.17). The rates associated with each currency denomination and loan/deposit type are estimated separately as shown in Table 3.1.

Recall from the model description that retail interest rates originate from imperfect spatial competition, and corporate rates are chosen in a perfectly competitive market. Let m =(Retail, Mortgage) denote the type of the interest rate

[10]Since banks' branching decisions depend on the setup costs and scrap values, these first–stage policy estimates are already functions of the unknown structural parameters. This is handled with an iterative formulation in the estimation.

Table 3.1: Description of Interest Rate Types.

Retail Loan Interest Rates	Mortgage Interest Rates
Hungarian Forint (HUF)	Hungarian Forint (HUF)
Euro (EUR)	Euro (EUR)
Swiss Franc (CHF)	Swiss Franc (CHF)
Retail Deposit Rates	**Corporate Loan Interest Rates**
Hungarian Forint (HUF)	Hungarian Forint (HUF)
Euro (EUR)	Euro (EUR)

offered to households. The following linear equations are estimated.

$$\left(r_l^h\right)_{jt}^m = \lambda_0^m + \lambda_1^m \cdot \left(c_l^h\right)_t^m + \lambda_2^m \cdot (\tilde{r})_t + \lambda_3^m \cdot \sum_{k \neq j} (n)_{kt} + \lambda_4^m \cdot (n)_{jt} + \lambda_5^m \cdot (I)_t + \nu_{jt}^m \tag{3.29}$$

where $\left(\lambda_1^m; \lambda_2^m; \lambda_4^m; \lambda_5^m\right) > 0$ and $\left(\lambda_3^m\right) < 0$,

$$\begin{aligned}\left(r_d^h\right)_{jt}^m = {} & \omega_0^m + \omega_1^m \cdot \left(c_d^h\right)_t^m + \omega_2^m \cdot (\tilde{r}\,(1-\phi))_t^m + \omega_3^m \cdot \sum_{k \neq j} (n)_{kt} + \omega_4^m \cdot (n)_{jt} \\ & + \omega_5^m \cdot (I)_t + \varphi_{jt}^m \end{aligned} \tag{3.30}$$

where $\left(\omega_2^m; \omega_3^m\right) > 0$ and $\left(\omega_1^m; \omega_4^m; \omega_5^m\right) < 0$,

$$\left(r_l^c\right)_{jt} = \rho_0 + \rho_1 \cdot \left(c_l^c\right)_t + \rho_2 \cdot (\tilde{r})_t + \psi_{jt} \tag{3.31}$$

where $(\rho_1; \rho_2) > 0$.

The proportional costs $\Psi = \left(c_l^h; c_d^h; c_l^c\right)$ are common across banks and vary over time. The elements of Ψ consist of three parts. The first part is the actual, monetary cost associated with making loans and taking deposits. The second term captures the currency risk associated with the given loan or deposit, and the third term represents expected currency appreciation. The first term (the monetary cost) is calculated by regressing the bank-specific loan and deposit quantities on each bank's *Total Variable Costs* each period as follows:

$$TVC_{jt} = \varrho_{0t} + \sum_{m} \varrho_{1t}^{m} (l)_{jt}^{m} + \sum_{m} \varrho_{2t}^{m} (d)_{jt}^{m} + \varrho_{3t} (n)_{jt} + \mu_{jt} \tag{3.32}$$

Equation (3.32) can be estimated by generalized least squares (GLS) with appropriate adjustments for the panel setting. In (3.32), the coefficients ϱ_{1t}^{m} and ϱ_{2t}^{m} capture the proportional *monetary* costs of making one unit's worth of loan of and deposit of type m. The currency risk term of the elements of Ψ is included with the purpose of capturing the riskiness of lending in any given currency (HUF, EUR or CHF). This currency risk is measured by calculating the volatility of each currency against the U.S. Dollar (USD) over the six months preceding each period t. The third term is measured as the average appreciation of the currency of the loan/deposit against the USD six months ahead of each period t.

Estimation of equations (3.29) through (3.31) by GLS for panel data yields parameter vector estimates $\left(\hat{\lambda}; \hat{\omega}; \hat{\rho}\right)$. The next step is then to get estimates of the optimal branch network size choice a_{jt}^{*} as a function of the state variables and structural parameters. The observed values of a_{jt} range from -6 to 6. This means that at most 6 branches are closed per period, and at most 6 branches are opened in each period. Assuming that the error term ε has the standard normal distribution, the probability that bank j chooses to open m_{jt} branches at time t can be expressed using the following ordered probit formulation. Let L_{jt} denote the linear equation such that[11]

$$L_{jt} = \kappa_0 + \kappa_1 \cdot (c_n)_t + \kappa_2 \cdot \sum_{k \neq j} (n)_{kt} + \kappa_3 \cdot (I)_t$$
$$+ \kappa_4 \cdot (n)_{jt} + +\kappa_5 \cdot (f_t) + \kappa_6 \cdot (e_t) + \varepsilon_{jt} = \kappa \cdot \tilde{\Theta}_{jt} \quad (3.33)$$

Then for the M_{jt} possible choices of how many new branches to add (in the present case, $M_{jt} = 10$), we have $M_{jt} - 1$ *cutoff values* $\varkappa\left(m_{jt}\right)$ such that

$$\text{Prob}\left(a_{jt} = m_{jt}\right) = \text{Prob}\left[\varkappa\left(m_{jt} - 1\right) \leq L_{jt} \leq \varkappa\left(m_{jt}\right)\right]$$
$$= \Phi\left[\varkappa\left(m_{jt}\right) - \kappa \cdot \tilde{\Theta}_{jt}\right] - \Phi\left[\varkappa\left(m_{jt} - 1\right) - \kappa \cdot \tilde{\Theta}_{jt}\right] \quad (3.34)$$

where $\Phi(\cdot)$ denotes the normal CDF of the error term ε_{jt}, and $\tilde{\Theta}_{jt}$ is the set of bank j–relevant period t state variables listed in Equation (3.33). It is apparent that the structural parameters $(f; e)_t$ already enter the first–stage policy functions. This problem is handled by solving the model iteratively. First, the observed interest rates and branch network size are used at the simulated second stage of the estimation, in order to get initial estimates of $(f; e)_t$. Then these initial estimates are used in the estimation of Equation (3.34). These steps are repeated until the structural parameter estimates converge.

The estimates $\hat{\kappa}$ from (3.34), together with the interest rate coefficient estimates $\left(\hat{\lambda}; \hat{\omega}; \hat{\rho}\right)$, can be used to construct the predicted branch network sizes and interest rates. The predicted policy functions are then used to write each bank's discounted sum of profits as functions of the model's state variables and the structural parameters only. However, a good understanding of the evolution of the model's exogenous state variables is also needed before constructing the discounted sum of expected profits. The transition probabilities of these state

[11]The coefficient estimate $\hat{\varrho}_{3t}$ from Equation (3.32) serves as data for the branch operational cost c_{nt} in (3.33).

variables in Θ can be estimated directly from their observed realizations over time.

3.4.2 Second Step: Structural Parameter Estimates

The unknown structural parameters to be estimated are the period–specific values of $\Xi_t = (f_t; e_t)$. The structural parameters are assumed to be common across banks, and vary over time. Let $\hat{\sigma} = \left(\hat{\lambda}; \hat{\omega}; \hat{\rho}; \hat{\kappa}\right)$ denote the vector of coefficient estimates from the first stage. Recall that α denotes the strategy set. The discounted sum of expected profits is described in (3.35) as the estimated counterpart of (3.25).

$$\psi_j(\Theta; n; \epsilon; \hat{\sigma}; \alpha; \Xi) = E\left[\Pi_j\left(\Theta; n_j; \epsilon; \hat{\sigma}; \alpha; \Xi\right) + v_j^{\sigma}\left(\Theta; n_j; \hat{\sigma}; \alpha; \Xi\right)\right] \tag{3.35}$$

Given the estimated transition probabilities, *forward simulation* is used to obtain the value function $\psi_j(\Theta; n; \epsilon; \hat{\alpha}; \Xi)$. For each simulation, first private shocks for each bank j are drawn. These are used together with the simulated paths of state variables to construct bank j's corresponding optimal branch network size and interest rate choices. The predicted policy functions yield $\hat{\Pi}_j(\cdot)$. Averaging bank j's discounted sum of profits over many simulated paths yields an estimate of $\psi_j(\cdot)$, denoted by $\hat{\psi}_j(\cdot)$. Comparing these simulated profit estimates (corresponding to banks' observed optimal choices, denoted by α) to the simulated values of many alternate paths of action (denoted by α') can then by used to recover the branch setup costs and scrap values as follows.

The MPE characterization above implies that at the true values of the structural parameters, denoted by Ξ_0, bank j's observed actions are optimal:

$$\psi_j\left(n_j; \epsilon_j; \alpha; \hat{\sigma}; \Theta; \Xi_0\right) \geq \psi_j\left(n_j; \epsilon_j; \alpha'_j; \alpha_{-j}; \hat{\sigma}; \Theta; \Xi_0\right) \tag{3.36}$$

The goal is to obtain estimates $\hat{\Xi}$ that minimize deviations from this set of inequalities. It is assumed that (1) all conditions for the point identification of the model are satisfied, and (2) the set of inequalities characterizing the optimal choices is large. Let x denote the equilibrium conditions. The function $g(x;\Xi)$ in (3.37) is defined based on (3.36) as follows:

$$g(x;\Xi;\alpha;\sigma) = \psi_j\left(n_j;\epsilon_j;\alpha;\sigma;\Xi\right) - \psi_j\left(n_j;\epsilon_j;\alpha'_j;\alpha_{-j};\sigma;\Xi\right) \tag{3.37}$$

Let $g_k(x;\Xi;\alpha;\sigma)$ denote the value of this difference for the k'th simulation, with empirical counterpart $\hat{g}_k(x;\Xi;\alpha;\sigma)$. Let S denote the number of alternate policy paths examined for each simulation, and K the total number of simulations. The following $Q_k(\Xi)$ function captures deviations from the set of inequalities described in (3.36).

$$Q_k(\sigma;\Xi) = \frac{1}{S}\sum_{s=1}^{S}\left[\min\left(\hat{g}_k(x;\Xi;\alpha;\sigma),0\right)\right]^2 \tag{3.38}$$

Then the best estimates of the structural parameters are such that

$$\hat{\Xi} := \arg\min_{\Xi} Q_k(\Xi;\hat{\sigma}_k) \tag{3.39}$$

It is assumed that all conditions which ensure that this estimator is consistent and asymptotically normal are satisfied. The values of $S-1$ alternate paths of action are simulated for each bank j and each simulation k. These sub–optimal paths are chosen to represent close deviations from the optimal (observed) path of actions. For instance, suppose that bank j opens m branches in period t. Then the second stage of the estimation consists of simulating the value associated with opening $z+h$ branches instead $\left(-\frac{S}{2} < h < \frac{S}{2}; h \neq 0\right)$. For J banks, this yields $J\cdot(S-1)$ data points per time period and simulation. Variation across simulation draws is then used to obtain the best structural parameter estimates according to (3.39).

3.4.3 Data

Detailed, regulatory balance sheet and interest rate data are collected by the Pénzügyi Szervezetek Állami Felügyelete (2004-2007) — the Hungarian Financial Supervisory Authority. Data are collected monthly on the activities of all Hungarian commercial banks. From this database, this chapter utilizes data on the five largest commercial banks operating in Hungary. The sample period is January 2004 through November 2007. Therefore, there are $47 \cdot 5 = 235$ data points in the panel for each type of bank activity.

Data on the choice (dependent) variables of the model (such as the interest rates and the branch network sizes) are directly available from the regulatory data set. Data on the state (explanatory) variables come from various sources. Data for marginal costs are estimated from the Total Variable Cost regression described in Equation (3.32) using confidential data on costs. Data on interbank lending rates, as well as required reserve ratios and other macro–level bank data, were collected from the Magyar Nemzeti Bank (2004-2007). Data on income, population, and market characteristics come from the Központi Statisztikai Hivatal (2004-2007). All quantities are reported in millions of HUF, which are converted to real terms using the GDP deflator. All the estimates are converted to elasticities, which are reported in Section 3.5.

3.5 Estimation Results

3.5.1 Interest Rates and Branch Network Choices

The following tables show the estimation results for the policy functions — corresponding to the first stage of the estimation. The results for the choices of optimal interest rates are described first, by type of interest rate.

Table 3.2 confirms that the retail lending rate estimation results are generally in line with the model's predictions. Accordingly, the interbank lending rate, marginal costs and the size of the own branch network have strong positive effects, and competitors' branch network size has a significant negative impact on banks' choice of retail lending rates. The results are the strongest for the HUF retail rates, and weaker for the EUR and CHF rates. It is interesting to note that per capita income — which the model predicts would be positively related to the choice of retail loan rates — appears with a negative sign for HUF and EUR loans. Furthermore, results show that as the currency of lending appreciates against the U.S. dollar, retail lending rates fall. The *sign* of this effect is in line with the predictions of Uncovered Interest Parity (UIP). However, UIP would imply that the coefficients on "E–R Appreciation" (against the USD) should equal one — which is clearly not the case.

Table 3.3 shows that the interbank lending and borrowing rates enter strongly and positively for both the deposit rates and the corporate lending rates. This is in line with the model's predictions. The predicted effect of branch network size is strongly confirmed by the data — banks with more branches set lower deposit rates. Greater branch network of competitors cause banks to offer higher

Table 3.2: Retail Loan Interest Rates: Elasticities.

Explanatory Variables	HUF Loan Rate Elast	EUR Loan Rate Elast	CHF Loan Rate Elast
Interbank Loan Rate	0.25^{**}(0.06)	0.12 (.27)	0.22 (.17)
Per Capita Income	-0.64^{*}(.31)	-0.59 (.67)	0.30 (78)
Currency Volatility	-0.01 (0.04)	0.04 (.09)	0.16^{**}(.07)
E-R Appreciation	-0.33^{***}(.14)	-0.04 (.12)	-0.21^{**}(.10)
Own Branch Number	0.08^{***}(.03)	0.12^{*}(.06)	0.47^{***}(.61)
Competitors' Branches	-0.37^{***}(.10)	-0.12 (.27)	-0.06 (.84)
MC of Lending	0.12^{*}(.07)	-0.66 (.76)	0.45 (.75)

deposit rates. Marginal costs have strong impacts on both the deposit and corporate rates. Currency volatility increases the lending rates that banks charge to firms. As expected, deposit rates decrease as the currency of deposits appreciates (in line with UIP), limiting arbitrage opportunities for banking clients. However, UIP fails again in that the estimated coefficients are far from unity. It is surprising that currency appreciation causes banks to charge higher rates to corporate customers.

Table 3.4 shows that a higher interbank rate has a strong positive impact on banks' mortgage rate choices, regardless of the currency. Per capita income appears to have a positive impact on mortgage rates. Having more branches allows banks to charge higher mortgage rates, while more branches of competitors cause them to charge lower rates. The marginal cost of lending increases

Table 3.3: Deposit Rates and Corporate Loan Interest Rates: Elasticities.

Explanatory Variables	HUF Dep Rate Elast	EUR Dep Rate Elast	HUF Firm Rate Elast	EUR Firm Rate Elast
Interbank Loan Rate	–	–	0.70^{***}(.00)	0.60^{***}(.12)
Interbank Deposit Rate	0.95^{***}(.03)	0.62^{**}(.26)	–	–
Per Capita Income	0.34^{*}(.19)	−0.13 (.42)	–	–
Currency Volatility	−0.01 (.02)	−0.02 (.08)	0.01^{***}(.00)	0.25^{***}(.04)
E-R Appreciation	-0.41^{***}(.14)	-1.19^{*}(.75)	0.08^{***}(.02)	1.10^{***}(.27)
Own Branch Number	-0.02^{**}(.01)	-0.08^{*}(.04)	–	–
Competitors' Branches	0.50^{***}(.10)	−0.02 (.18)	–	–
MC of Lending	–	–	0.48^{***}(.03)	0.08 (.07)
MC of Deposits	−0.99 (.36)	−0.24 (.22)	–	–

mortgage rates of all currencies significantly. As expected, currency appreciation enters the choice of all mortgage rates with a negative sign (in line with UIP). However, none of the coefficients on currency appreciation are significant.

Section 3.4 describes the ordered probit estimation of banks' choice of branch network expansion. Instead of reporting the elasticities of each branch expansion choice one by one, it is more informative to separate banks' branch network decisions into two categories: the decision to *open* or *close* branches. Table 3.5 presents the results of the probit estimation — the effects of the model's state variables on the probability of branch network expansion.

Table 3.4: Mortgage Interest Rates: Elasticities.

Explanatory Variables	HUF Mort Rate Elast	EUR Mort Rate Elast	CHF Mort Rate Elast
Interbank Loan Rate	0.47^{***}(.06)	1.73^{**}(.71)	0.40 (.27)
Per Capita Income	−0.10 (.30)	3.22^{***}(0.94)	2.49^{*}(1.43)
Currency Volatility	0.08^{**}(.04)	−0.06 (.19)	-0.20^{*}(.12)
E-R Appreciation	−0.06 (.27)	−1.83 (1.72)	−1.55 (1.14)
Own Branch Number	0.08^{***}(.03)	0.23^{**}(.10)	1.95 (1.17)
Competitors' Branches	−0.13 (.14)	-1.49^{***}(.27)	2.05 (1.41)
MC of Lending	0.96^{*}(.52)	0.31 (.41)	0.75 (1.20)

Table 3.5: Branch Network Expansion Probability: Elasticities.

Explanatory Variables	Branch Opening Probability
Own Branch Number	-0.26^{***}(.11)
Competitors' Branches	1.21^{**}(.55)
Branch Oper. Cost	−0.20 (.44)
Per Capita Income	2.30^{*}(1.24)
Branch Setup Cost	-1.11^{**}(.52)
Branch Scrap Value	1.14^{**}(.51)

Table 3.5 confirms that having a bigger branch network reduces the probability that banks would choose to add new branches. However, more branches of competitors induce banks to expand their own branch network. Branch operational costs (incorporating variable day to day costs of operation) have a weak negative effect. Greater per capita income (potentially a proxy for the demand for banking services) has a significant positive impact on the probability that banks add new branches. As expected, the fixed per–branch setup costs (incorporating values of real estate and equipment) have a significant negative, while the scrap value of branches has a significant positive impact on the probability that banks expand their branch network size.

3.5.2 Branch Setup Costs and Scrap Values

With the policy function estimates in hand, forward simulation is used to obtain values for banks' discounted expected sum of profits. Transition probabilities for the time–varying exogenous state variables are estimated first. These variables are per capita income, the currency volatilities and appreciations, the interbank rates, the branch network size of competitors, the marginal costs and the branch operational costs. Second stage estimates of branch setup costs and scrap values are derived using the transition probabilities and the first–stage policy function estimates. The month–by–month setup cost and scrap value estimates are summarized in Table 3.6 and detailed in Table 3.7. Figure 3.8 depicts the estimates over time. On average, the setup cost of a branch is 2.48 times bigger than its scrap value. Since the growth rates of branch setup costs and scrap values are 2.03 percent and 1.83 percent respectively, the discrepancy between the two is growing over the sample period.

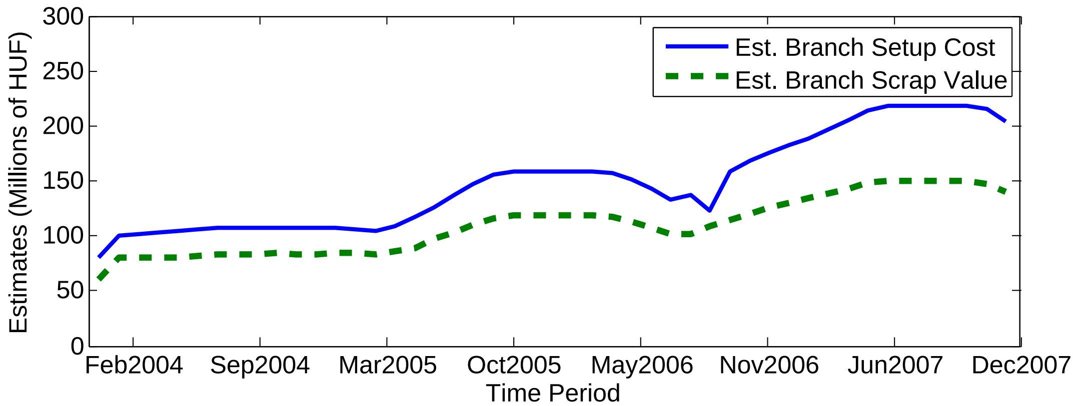

Figure 3.8: Estimated Branch Setup Costs and Scrap Values Over Time.

Table 3.6: Summary Statistics (Millions of HUF).

Parameter	Min	25p	50p	75p	Max	Mean	Std Dev
Setup Cost	80.00	107.86	147.23	182.03	218.43	148.81	41.92
Scrap Value	60.00	83.70	110.43	129.63	149.54	109.48	25.37

Table 3.7: Branch Setup Cost and Scrap Value Estimates (Millions of HUF).

Time Period	Branch Setup Cost	Branch Scrap Value
Jan 04	$80.00^{***}(.18)$	$60.00^{***}(1.53)$
Feb 04	$100.51^{***}(.27)$	$80.01^{**}(37.97)$
Mar 04	$101.68^{***}(.44)$	$80.86^{***}(18.63)$

Table 3.7: (Continued)

Time Period	Branch Setup Cost	Branch Scrap Value
Apr 04	103.07***(.54)	80.51 (212.51)
May 04	104.60***(.48)	81.03 (155.75)
June 04	106.00***(.59)	81.78 (123.38)
July 04	107.39***(.70)	82.64 (122.52)
Aug 04	107.86***(1.18)	83.16***(23.76)
Sept 04	107.86***(1.43)	83.13***(30.25)
Oct 04	107.86***(1.18)	84.58***(22.02)
Nov 04	107.86***(1.17)	83.70***(21.34)
Dec 04	107.86***(1.28)	82.83***(19.37)
Jan 05	107.40***(3.08)	84.39***(31.97)
Feb 05	106.48***(6.12)	83.90 (95.76)
Mar 05	105.10***(4.63)	83.14***(13.28)
Apr 05	109.29***(3.19)	86.15***(19.62)
May 05	116.75***(1.19)	88.52***(15.38)
June 05	126.38***(1.38)	97.43 (81.12)
July 05	137.09***(3.64)	102.94***(13.72)
Aug 05	147.23***(1.96)	110.43***(16.91)
Sept 05	155.13***(4.56)	115.86 (156.58)
Oct 05	158.86***(5.79)	118.06 (152.53)

Table 3.7: (Continued)

Time Period	Branch Setup Cost	Branch Scrap Value
Nov 05	158.86^{***}(6.01)	118.06 (100.93)
Dec 05	158.86^{***}(6.78)	118.06 (86.94)
Jan 06	158.86^{***}(8.70)	118.06 (151.06)
Feb 06	158.86^{***}(10.28)	118.06 (332.71)
Mar 06	157.67^{***}(8.87)	117.12 (195.01)
Apr 06	151.56^{***}(8.94)	113.03^{*}(67.60)
May 06	142.90^{***}(14.68)	107.31 (138.27)
June 06	133.52^{***}(8.73)	101.16 (139.56)
July 06	137.70^{***}(8.17)	102.34 (111.63)
Aug 06	123.25^{***}(13.60)	108.70 (100.37)
Sept 06	158.82^{***}(12.53)	115.12 (88.44)
Oct 06	167.93^{***}(13.27)	120.52 (92.76)
Nov 06	175.26^{***}(16.26)	125.27 (81.22)
Dec 06	182.03^{***}(4.91)	129.63 (70.28)
Jan 07	188.98^{***}(9.77)	133.95 (135.63)
Feb 07	196.59^{***}(11.76)	138.54 (85.84)
Mar 07	204.79^{***}(25.50)	143.35^{***}(14.86)
Apr 07	214.48^{***}(11.14)	148.21^{***}(18.59)
May 07	218.42^{***}(13.17)	149.54^{***}(23.56)

Table 3.7: (Continued)

Time Period	Branch Setup Cost	Branch Scrap Value
June 07	218.42^{***}(8.08)	149.54^{***}(25.72)
July 07	218.42^{***}(11.26)	149.54^{***}(18.77)
Aug 07	218.42^{***}(9.67)	149.54^{***}(27.01)
Sept 07	218.42^{***}(9.94)	149.54^{***}(54.88)
Oct 07	214.94^{***}(8.15)	146.68^{**}(69.74)
Nov 07	203.65^{***}(9.46)	139.44^{*}(76.19)

Table 3.8 shows the relationship between measures of the cost of construction, and estimates of the branch setup costs and scrap values. Setup cost and scrap value estimates are strongly positively correlated, and both move closely with relevant producer price indices.

Table 3.8: Correlations.

Measures	Setup Cost	Scrap Value
Scrap Value	0.99^{***}	
Manufacturing PPI	0.89^{***}	0.90^{***}
Industrial PPI	0.92^{***}	0.93^{***}
Investment PPI	0.88^{***}	0.90^{***}

3.6 Simulation Exercises

This section explores the impact of increasing various model parameters on banks' optimal behavior. In particular, arc elasticities of bank interest rate and branch network size choices with respect to setup costs, consumer income, and competitors' branch network size are reported.

3.6.1 Increasing Branch Setup Costs

This subsection examines the effect of a one–time increase in the initial value of branch setup cost on the behavior of the average bank throughout the course of the sample period. Figure 3.9 displays the negative relationship between setup cost increases and the arc elasticity of the probability of branch network expansion. The arc elasticity is small, and decreasing in magnitude – implying that expansion probabilities are concave in setup costs.

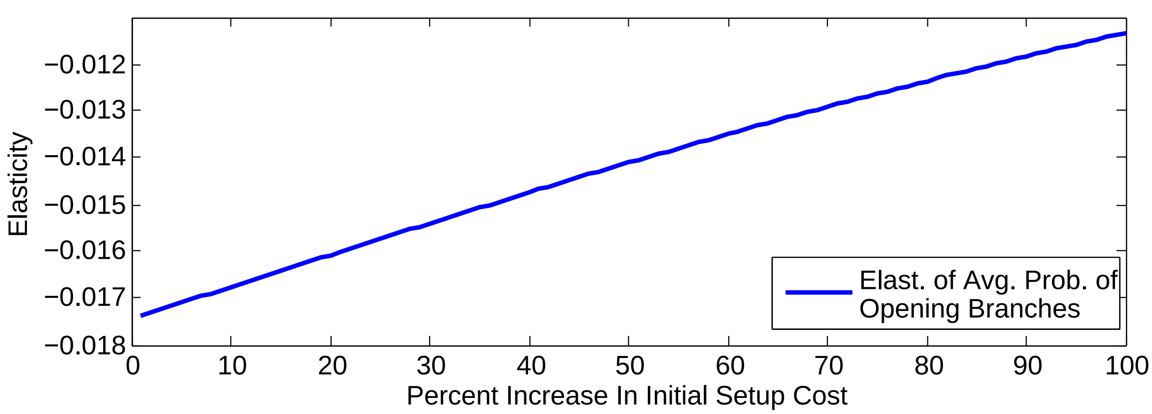

Figure 3.9: Elasticity of Branch Opening Probability w.r.t. Setup Cost.

3.6.2 Increasing Consumer Income

This exercise explores the effects of gradual percent increases in per capita consumer income on indicators of bank profitability and bank behavior. Increases in income impact the choices of all interest rates, as well the the size of the branch network. Figure 3.10 explores the impact of increases in per capita income on the average bank's Net Interest Income (NII), a common measure of profitability. It shows that at low levels of initial income, a 1 percent increase in income raises NII by 2.5 percent over the length of the sample period (strongly elastic). However, this arc elasticity decreases with income, to a steady level of 0.25 in the inelastic range – implying that NII is increasing concave in consumer income.

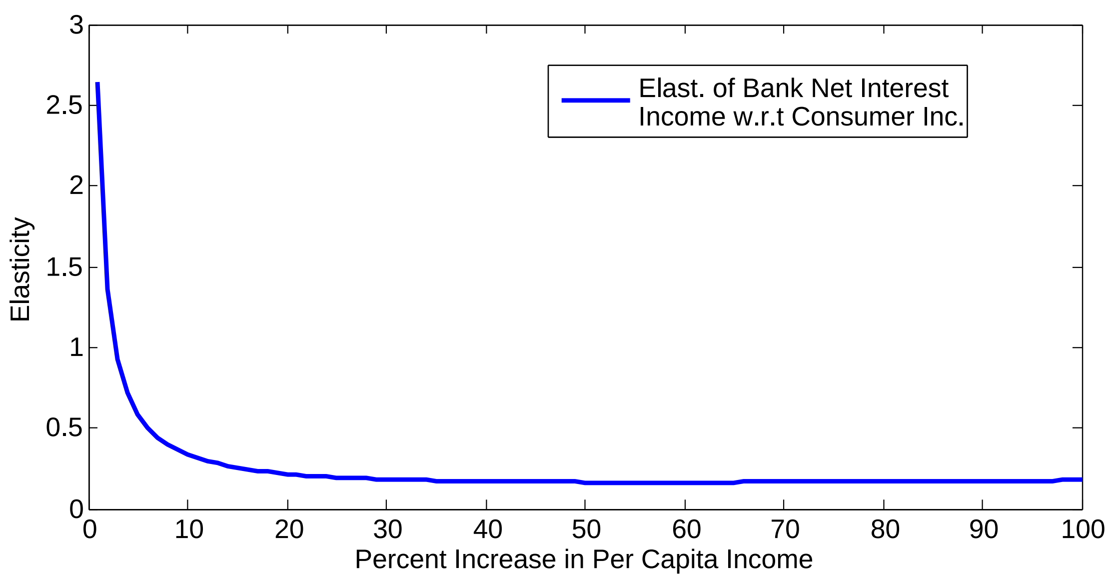

Figure 3.10: Elasticity of Net Interest Income w.r.t. Per Capita Consumer Income.

Figure 3.11 explores the effect of increases in income on the elasticity of the average bank's own branch network size. The depicted positive relationship is in line with the results presented in Table 3.5. The per capita income arc elasticity of branch network size increases from 0.31 to 0.35 as income increases (consistently in the inelastic range) — implying that branch network size is increasing convex in consumer income.

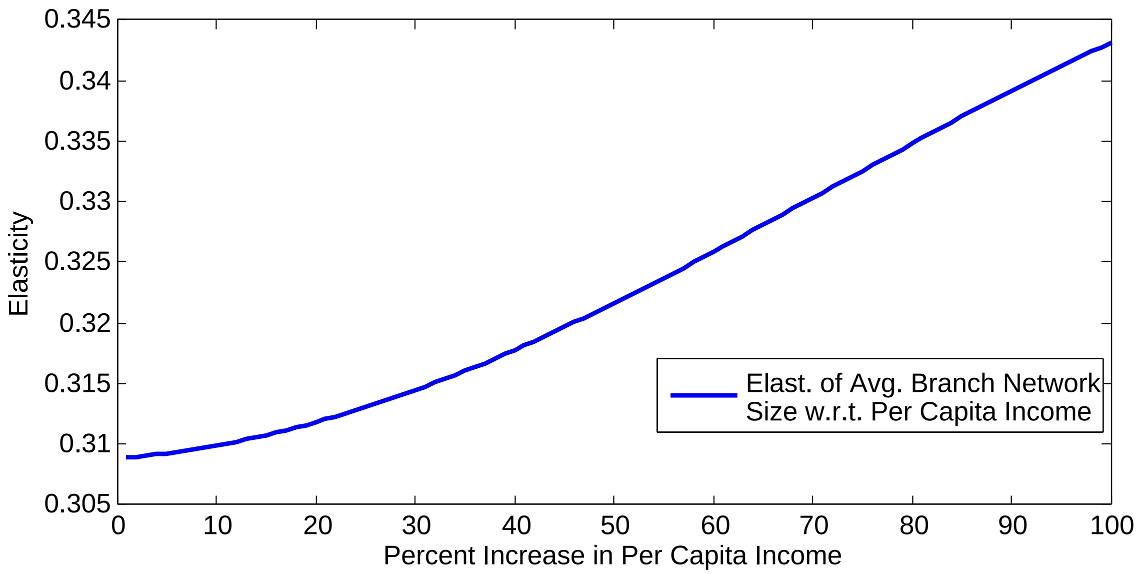

Figure 3.11: Elasticity of Branch Network Size w.r.t. Per Capita Consumer Income.

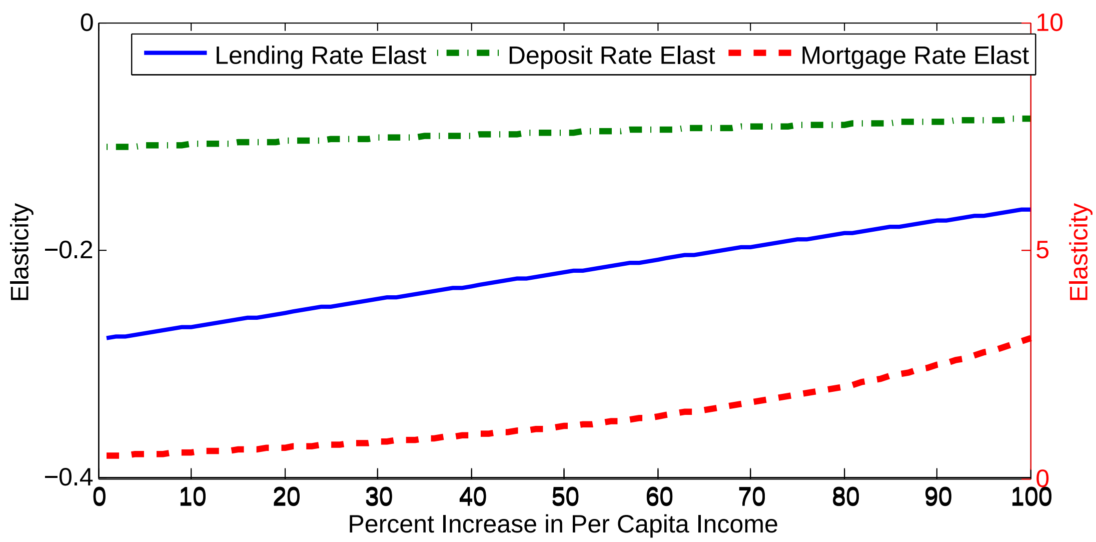

Figure 3.12: Elasticities of Interest Rates w.r.t. Per Capita Consumer Income.

Figure 3.12 shows the impact of income increases on banks' choices of interest rates. Both the average retail lending and deposit rates respond negatively to rises in income, depicting a negative concave relationship. Mortgage rates, on the other hand, are strongly elastic and increasing convex in consumer income. These results are in line with the estimates presented in Section 3.5.

3.6.3 Increasing Competitors' Branch Network Size

This simulation exercise explores the impact of increases in competitors' branch network size on the average bank's optimal behavior. Figure 3.13 shows how the average bank's Net Interest Income (NII) responds to increases in the branch network size of competitors. At the observed numbers of competitors' branches, a 1 percent increase in their network size causes average bank NII to fall by over 8 percent. However, this negative impact dampens quickly as competitors' network size rises. In fact, at numbers twice as big as the observed values, the response of average bank NII to rises in competitors' branch network size becomes positive.

Figure 3.14 shows the impact of competitors' branch network size on the own network size of the average bank. This effect is weakly positive, and greater at higher levels of competitors' network size (in the 0.23 to 0.25 range) — implying an increasing convex relationship in line with Table 3.5. It appears that branch network competition becomes more intense when the overall branch network is greater.

Figure 3.15 depicts the impact of rises in competitors' branch network size

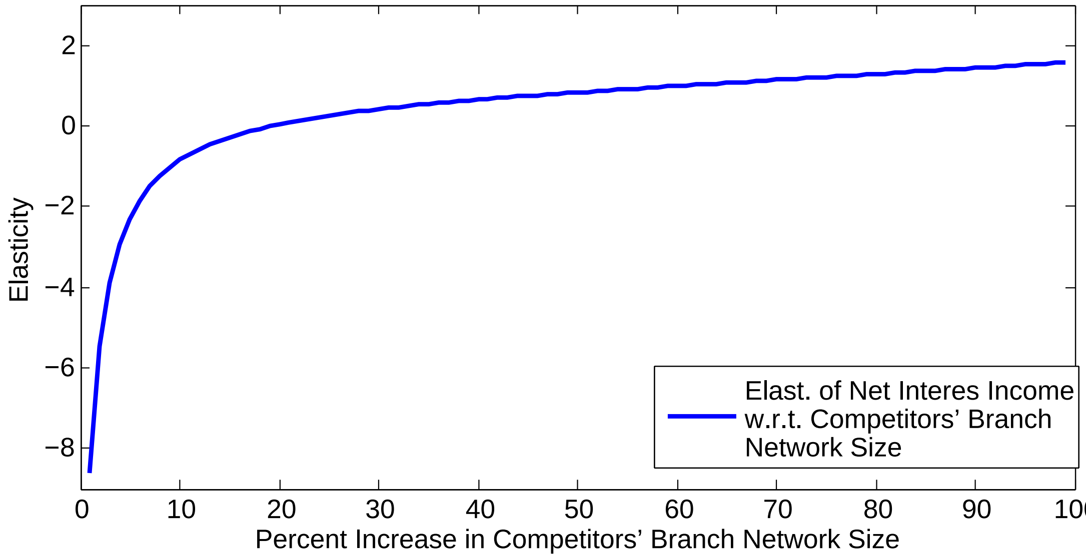

Figure 3.13: Elasticity of Net Interest Income w.r.t. Competitors' Branch Network Size.

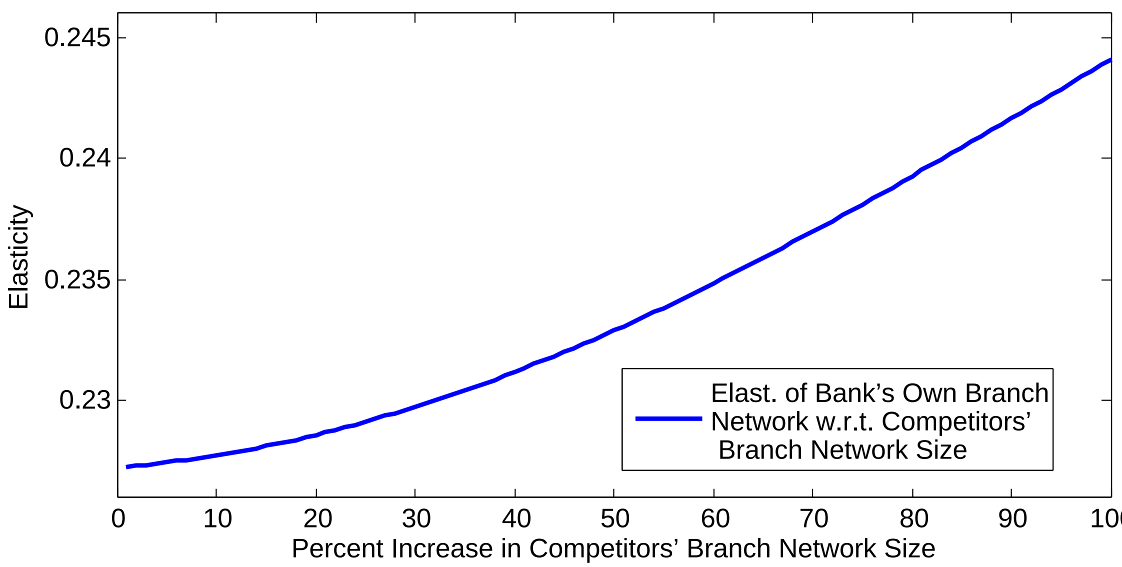

Figure 3.14: Elasticity of Branch Network Size w.r.t. Competitors' Branch Network Size.

on the average bank's choices of interest rates. As expected, the average bank offers higher deposit rates and demands lower loan rates as the number of competitors' branches increases. Mortgage rates, however, respond positively on average. This is due to the strong positive elasticity of CHF mortgages which outweighs the negative response of HUF and EUR mortgages, as described in

Section 3.5 above.

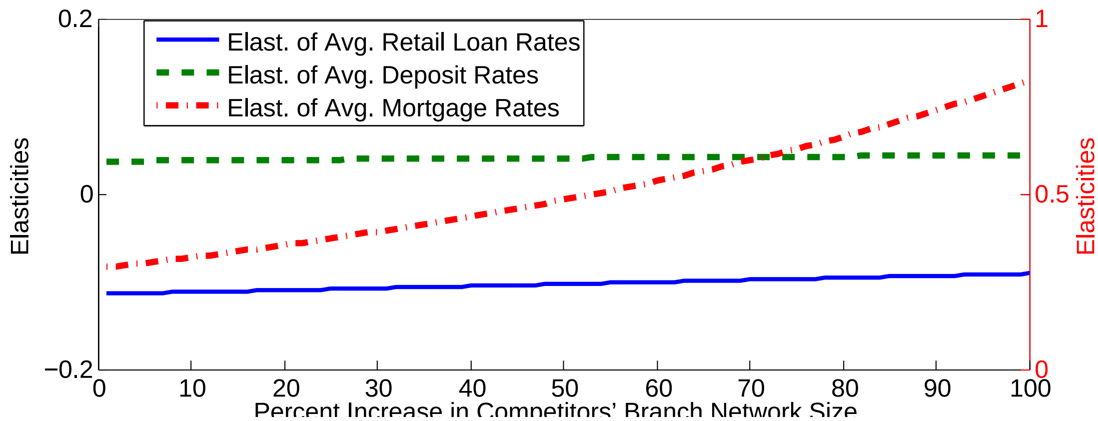

Figure 3.15: Elasticity of Interest Rates w.r.t. Competitors' Branch Network Size.

Comparing the effects of increases in per capita consumer income and competitors' branch network size, it is interesting to note that the *signs* of the impacts are very similar (with the notable exception of the response of retail lending rates). However, the *magnitudes* are rather different. The effects of per capita consumer income increases are consistently greater than the impacts of increases in competitors' branch network size.

3.7 Summary

The purpose of this chapter is to provide a thorough examination of the competitive behavior of Hungarian commercial banks in a dynamic framework. The study presented in this chapter contributes to the previous literature by incorporating branch network competition (in addition to interest rate competition) of imperfectly competitive commercial banks in a dynamic setting. Furthermore,a model–based approach is used to estimate structural parameters (branch setup costs and scrap values) that so far have been only approximated by ad hoc empirical measures.

The chapter develops a model of branch network and interest rate competition, where banks simultaneously make retail lending, mortgage, deposit interest rate, as well as branch network size decisions. Banks take into account the impact of their choices on their future profits. Banks' optimal interest rate and branch network size choices are characterized in the Salop competition framework. Comparative statics predictions about the impact of the model's state variables (such as marginal costs, branch operational costs, interbank rates) on banks' optimal choices are derived. A version of the Bajari, Benkard, and Levin (2007) two–stage estimation method is developed to estimate the policy equations, and to obtain estimates of the branch setup costs and scrap values.

Results corresponding to the first stage of the estimation (the static policy function estimates) show that own and competitors' branch network sizes have a strong impact on banks' interest rate choices. This finding confirms the conclusions of the previous literature (Dick, 2007; Spieker, 2004) that consumers care much about the proximity and availability of bank branches (which banks charge a premium for). When competitors have more branches, the average bank compensates by lowering its lending rates and paying higher rates on deposits. Furthermore, banks' propensity to build new branches decreases in the size of their existing network. Competition in bank branch network size is confirmed by the result that greater branch network size of competitors induce banks to expand their own network as well. Furthermore, banks add fewer new branches if their operation is more expensive, and if branches cost more to build.

Banks are more likely to add new branches if the scrap values are high.

The second stage of the dynamic estimation obtains estimates of the fixed setup costs (and scrap values) of bank branch network expansion (and contraction). The per–bank setup cost (with an average of approximately 150 million HUF, or about 0.75 million USD) is 2.48 times greater than the mean scrap value (with an average of 110 million HUF, or approximately 0.55 million USD). As branch setup costs grow faster than scrap values, the discrepancy between the two is growing over the sample period.

Simulation exercises are conducted to examine the impacts of rises in branch setup costs, per capita consumer income and competitors' branch network size on the optimal behavior of the average bank. Branch setup costs only have a very small negative impact on bank profitability (as measured by Net Interest Income), and negligible effect on interest rates. The choice of branch network size has a negative response, as expected. Rising per capita consumer income and competitors' branch network size have strong effects on bank behavior — confirming the important roles of consumer traits (the demand side) and competitive behavior (the supply side). This chapter provides a careful study of the credit supply side — a contribution to a literature that focuses heavily on the demand (consumer) side of banking in Hungary. The results presented in this paper can therefore have important policy implications from the perspective of bank regulators.

APPENDIX A

CHAPTER 2

A.1 Data Appendix

Initial Capitalization. Data on Initial capitalization come from the FFIEC Country Exposure Surveys. For each bank size category, the reported Total Assets are divided by the number of banks to get a value for the *average* bank representative of the given bank size category. The data are reported in million USD, and are converted into real terms using 2005 Q4 as the base. Values are in log of million USD.

Expected Loan and Deposit Rate Indices. Data used for the variables α_i and β_i are market–specific loan and deposit rate indices, collected from Economist Intelligence Unit (1997-2005)'s Country Data . Averages of these α's and β indices are taken over a 3–quarter rolling window, in order to represent the bank's expectation of these values.

Proportional Lending and Deposit Costs. Total Costs are regressed on loan and deposit volumes and a constant in each market. The coefficients on the affiliate loan and deposit volumes are used as measures of proportional lending and deposit costs, respectively. Cross–border lending cost is measured as the coefficient on cross–border loans in the U.S. Total Cost regression.

Proportional Income Tax Rates and Basic Borrowing Costs. Since data on tax rates applicable to bank income are not available, these tax rates are approx-

Table A.1: Loan & Deposit Averages by Country Over Time (log millions of 2005 Q4 USD).

Code	Aff. Loan	CB Loan	Dep.	Code	Aff. Loan	CB Loan	Dep.
AR	4.79	4.80	5.20	JA	4.87	5.45	4.58
AU	4.92	4.90	5.00	LU	2.50	3.86	4.38
AT	1.57	4.63	1.68	MY	2.87	2.79	2.72
BE	2.01	5.18	3.00	MX	4.77	5.88	4.47
BR	6.78	5.72	6.89	NL	2.16	6.08	3.02
BG	2.52	0.85	2.96	NZ	3.85	2.56	3.12
CA	6.30	5.80	6.05	NO	1.99	3.86	1.12
CL	5.86	4.19	5.85	PH	5.43	3.88	5.41
CN	4.21	3.29	3.33	PL	6.38	1.71	6.28
CO	4.51	3.73	4.23	PT	4.55	3.31	4.68
CZ	5.22	1.22	5.59	RO	3.85	0.51	3.93
DK	1.13	4.73	0.81	RU	4.39	2.81	4.26
FI	−0.34	3.11	−0.05	SG	3.51	4.34	4.64
FR	2.54	5.99	2.41	SK	4.44	1.14	4.38
DE	4.02	6.50	4.25	ZA	5.64	3.09	5.96
GR	6.14	3.21	6.46	KR	4.22	5.11	2.95
HU	5.00	1.11	5.18	ES	4.30	4.47	3.62
IS	−1.29	0.98	−1.15	SE	2.14	4.65	1.52
IN	6.44	3.59	6.83	CH.	2.66	5.08	2.28
ID	5.35	3.06	5.69	TH	2.02	2.74	1.86
IE	3.15	4.60	3.42	TR	5.17	4.20	5.04
IL	4.38	3.69	3.91	UK	7.13	7.21	7.46
IT	4.02	5.05	2.98	US	11.57	–	11.57

Table A.2: Loan & Deposit Averages by Time Period Across Countries (log millions of 2005 Q4 USD).

Time	Aff Loans	CB Loans	Deps	Time	Aff Loans	CB Loans	Deps
97/12	4.38	3.59	4.42	02/03	4.15	3.98	4.21
98/03	4.29	3.65	4.43	02/06	4.13	3.96	4.42
98/06	4.18	3.74	4.13	02/09	4.16	3.95	4.31
98/09	4.27	3.69	4.40	02/12	4.35	3.91	4.31
98/12	4.31	3.67	4.44	03/12	4.45	3.92	4.36
99/12	4.36	3.66	4.22	03/06	4.43	3.96	4.37
99/06	4.24	3.71	4.45	03/09	4.35	4.00	4.37
99/12	4.39	3.73	4.60	03/12	4.38	4.09	4.41
99/12	4.47	3.67	4.51	04/03	4.29	4.11	4.26
00/03	3.83	3.66	4.16	04/06	4.46	4.15	4.33
00/06	4.52	3.08	4.09	04/09	4.77	4.24	4.06
00/09	4.12	3.80	3.81	04/12	4.66	4.17	4.46
00/12	4.31	3.69	3.94	05/12	4.54	4.26	4.48
01/03	4.31	3.80	3.99	05/06	4.25	4.20	4.41
01/06	4.27	3.95	4.43	05/09	4.51	4.31	4.54
01/09	4.10	3.92	4.22	05/12	4.45	4.30	4.86
01/12	3.19	3.98	3.11				

Table A.3: Summary of Explanatory Variables.

Variable Name	Note	Empirical Measure
Cross-Border Loan in i	l^i_{cbj}	Bank's CB claims in i, mill 2005 USD
Affiliate Loan in i	l^i_{aj}	Bank's claims in i, mill 2005 USD
Foreign Aff Dep' in i	d^i_j	Bank's FA liabs in i, mill 2005 USD
Bank Scope	S_j	Lagged Sharpe Ratio
Initial Bank Capital	K_j	Bank's Total Assets, mill 2005 USD
Expected Aff	$\bar{\alpha}^i_a$	Mean of predicted aff loan
Loan market return in i		mkt return in i over 3-qtr window
Expected Deposit	$\bar{\beta}^i_a$	Mean of predicted deposit
market return in i		mkt return in i over 3-qtr window
Expected CB Loan	$\bar{\alpha}^i_{cb}$	Mean of predicted CB loan
market return in i		mkt return in i over 3-qtr window
Lending Cost	c^i_{lj}	Stock mkt Return in i - ROA
Deposit-taking cost	c^i_d	Deposit rate - money mkt rate
Income Tax Rate	t^i	Corporate Tax Rate in i
Req. Reserve Ratio in i	δ^i	Required Reserve Ratio in i
Bank's Risk Aversion	λ_j	Estimated from Model
Capital Adequacy	$\bar{k}^i$	Minimum Cap. Ratio in i
Basic Cost of Other	$\bar{r}^i_\Delta$	Basic 'riskless' interest rate set by
Borrowing in i		the monetary authority in i
Loan Deman Elast.	ϵ^i_m	Estimated Coefficient
Deposit S. Elast in Deposit	η^i	Estimated Coefficient
Regulator's Risk Avers. in i	θ^i	Estimated from Model
Entry Cost & Scrap Value in i	Γ^i	Estimated from Model

imated with corporate income tax rates taken from the Organisation for Economic Co-operation and Development (1997-2005)'s database. The basic cost of non–deposit borrowing is measured using the country–specific equivalent of the federal funds rate, set by the monetary authority in market i (the equivalent of the federal funds rate). Data on these interest rates are collected from the International Monetary Fund (1997-2005)'s International Financial Statistics.

Required Reserve Ratio and Minimum Capital Ratio. Data on market–specific required reserve ratios and minimum capital ratios are collected from the World Bank (1997-2005)'s Bank Regulation and Supervision database. Where not available, the ratios are directly taken from national central banks' websites.

Data on Loan Demand and Deposit Supply Elasticities. Taking logs of the Dixit-Stiglitz form of the loan demand equation yields: $\log l^i_m = \log \alpha^i_m - \epsilon^i \cdot r^i_{lm}$ where r^i_{lm} is the lending rate in market m. The coefficient ϵ^i_m from this regression is used as loan demand elasticity. Similarly, the deposit supply equation is $\log d^i = \log \beta^i + \eta^i \cdot r^i_d$, from which the deposit supply elasticity in country i is measured as the coefficient η^i.

Bank Scope. Initial bank scope is measured as the lagged Sharpe ratio.

Loan & Deposit Volumes. Tables A.1 and A.2 present averages of the loans & deposits by country and by time period, respectively. Table A.3 summarizes notation and empirical measures used for the explanatory variables in this chapter.

Summary Statistics. Table A.4 presents summary statistics.

Table A.4: Summary Statistics of Variables.

Name	Min	25p	50p	75p	Max	Std Dev
Log of CB Loans	−4.25	1.85	4.25	6.13	9.06	2.85
Log of Affil Loans	−4.44	1.58	4.99	6.70	13.58	3.52
Log of Affil Dep's	−4.44	1.37	5.11	6.71	13.61	3.59
Log of Bank Capital	9.60	9.99	10.39	12.99	13.84	1.47
Exp. Loan market return in i	1.38	5.60	8.30	13.30	97.7	15.21
Exp. Deposit return in i	0.06	2.25	3.67	7.75	87.36	10.64
Exp. CB Loan return in i	0.02	2.7	4.59	7.67	174.72	12.80
Proportional Cost	0.09	0.38	0.72	1.79	30.21	2.76
Income Tax Rate	10	28	33	35.70	57.5	7.38
Req Reserve Ratio	0	2	4	10	34	7.51
Min Capital Ratio	8	8	8	8	16	1.45
Nondep Borrow Cost	0	4.24	5.40	8.26	105.72	12.87
Affil Loan Elast in i	0	.05	0.27	0.55	8.68	1.27
Dep Supply Elast	0	0.06	0.30	1.15	2.96	0.78
CB Loan Elast	0	0.05	0.09	0.19	1.99	0.32
Lag Sharpe Ratio	2.78	3.23	3.32	3.70	3.78	0.27
Sharpe Ratio						

APPENDIX B

CHAPTER 3

B.1 Model Appendix

Using the optimality condition in (3.15), the Implicit Function Theorem implies

$$
\begin{aligned}
\frac{\partial r^h_{lj}}{\partial n_j} &= -\left[\frac{\frac{\partial E\left(L^h_j\right)}{\partial n_j} + \left(r^h_{lj} - \tilde{r} - c^h_{lj}\right)\frac{\partial^2 E\left(L^h_j\right)}{\partial r^h_{lj}\partial n_j}}{2\frac{\partial E\left(L^h_j\right)}{\partial r^h_{lj}} + \left(r^h_{lj} - \tilde{r} - c^h_{lj}\right)\frac{\partial^2 E\left(L^h_j\right)}{\partial r^{h2}_{lj}}}\right] > 0 \\
\frac{\partial r^h_{lj}}{\partial \tilde{r}} = \frac{\partial r^h_{lj}}{\partial c^h_{lj}} &= -\left[\frac{-\frac{\partial E\left(L^h_j\right)}{\partial r^h_{lj}}}{2\frac{\partial E\left(L^h_j\right)}{\partial r^h_{lj}} + \left(r^h_{lj} - \tilde{r} - c^h_{lj}\right)\frac{\partial^2 E\left(L^h_j\right)}{\partial r^{h2}_{lj}}}\right] > 0 \\
\frac{\partial r^h_{lj}}{\partial n_{-j}} &= -\left[\frac{\frac{\partial E\left(L^h_j\right)}{\partial n_{-j}} + \left(r^h_{lj} - \tilde{r} - c^h_{lj}\right)\frac{\partial^2 E\left(L^h_j\right)}{\partial r^h_{lj}\partial n_{-j}}}{2\frac{\partial E\left(L^h_j\right)}{\partial r^h_{lj}} + \left(r^h_{lj} - \tilde{r} - c^h_{lj}\right)\frac{\partial^2 E\left(L^h_j\right)}{\partial r^{h2}_{lj}}}\right] < 0 \\
\frac{\partial r^h_{lj}}{\partial I} &= -\left[\frac{\frac{\partial E\left(L^h_j\right)}{\partial I} + \left(r^h_{lj} - \tilde{r} - c^h_{lj}\right)\frac{\partial^2 E\left(L^h_j\right)}{\partial r^h_{lj}\partial I}}{2\frac{\partial E\left(L^h_j\right)}{\partial r^h_{lj}} + \left(r^h_{lj} - \tilde{r} - c^h_{lj}\right)\frac{\partial^2 E\left(L^h_j\right)}{\partial r^{h2}_{lj}}}\right] > 0
\end{aligned}
\tag{B.1}
$$

In all of the derivatives in Equation (B.1), the denominators are negative due to the second–order condition for a maximum holding. Equation (3.12) implies that the numerator in the top row of (B.1) is positive. Therefore, bank j's own rate increases in the number of branches it operates. By the law of demand, the numerator in the second row of (B.1) is positive — therefore, the optimal retail lending rate increases in both the interbank lending rate and the marginal cost of retail lending. Equation (3.12) implies that the numerator in the third row of (B.1) is negative — therefore, larger branch network size by other banks causes bank j to lower its optimal choice of the retail lending rate. In the bottom row of Equation (B.1), the sign of the numerator is positive — therefore, higher per capita income leads to higher lending rates.

$$
\begin{aligned}
\frac{\partial r_{dj}^{h}}{\partial n_j} &= -\left[\frac{-\frac{\partial E\left(D_j^h\right)}{\partial n_j}+\left(\tilde{r}\left(1-\phi\right)-r_{dj}^{h}-c_{dj}^{h}\right)\frac{\partial^2 E\left(D_j^h\right)}{\partial r_{dj}^{h}\partial n_j}}{-2\frac{\partial E\left(D_j^h\right)}{\partial r_{dj}^{h}}+\left(\tilde{r}\left(1-\phi\right)-r_{dj}^{h}-c_{dj}^{h}\right)\frac{\partial^2 E\left(D_j^h\right)}{\partial r_{dj}^{h2}}}\right] < 0 \\
\frac{\partial r_{dj}^{h}}{\partial \tilde{r}} &= -\left[\frac{\left(1-\phi\right)\frac{\partial E\left(D_j^h\right)}{\partial r_{dj}^{h}}}{-2\frac{\partial E\left(D_j^h\right)}{\partial r_{dj}^{h}}+\left(\tilde{r}\left(1-\phi\right)-r_{dj}^{h}-c_{dj}^{h}\right)\frac{\partial^2 E\left(D_j^h\right)}{\partial r_{dj}^{h2}}}\right] > 0 \\
\frac{\partial r_{dj}^{h}}{\partial c_{lj}^{h}} &= -\left[\frac{-\frac{\partial E\left(D_j^h\right)}{\partial r_{dj}^{h}}}{-2\frac{\partial E\left(D_j^h\right)}{\partial r_{dj}^{h}}+\left(\tilde{r}\left(1-\phi\right)-r_{dj}^{h}-c_{dj}^{h}\right)\frac{\partial^2 E\left(D_j^h\right)}{\partial r_{dj}^{h2}}}\right] < 0 \qquad \text{(B.2)} \\
\frac{\partial r_{dj}^{h}}{\partial n_{-j}} &= -\left[\frac{-\frac{\partial E\left(D_j^h\right)}{\partial n_{-j}}+\left(\tilde{r}\left(1-\phi\right)-r_{dj}^{h}-c_{dj}^{h}\right)\frac{\partial^2 E\left(D_j^h\right)}{\partial r_{dj}^{h}\partial n_{-j}}}{-2\frac{\partial E\left(D_j^h\right)}{\partial r_{dj}^{h}}+\left(\tilde{r}\left(1-\phi\right)-r_{dj}^{h}-c_{dj}^{h}\right)\frac{\partial^2 E\left(D_j^h\right)}{\partial r_{dj}^{h2}}}\right] > 0 \\
\frac{\partial r_{dj}^{h}}{\partial I} &= -\left[\frac{-\frac{\partial E\left(D_j^h\right)}{\partial I}+\left(\tilde{r}\left(1-\phi\right)-r_{dj}^{h}-c_{dj}^{h}\right)\frac{\partial^2 E\left(D_j^h\right)}{\partial r_{dj}^{h}\partial I}}{-2\frac{\partial E\left(D_j^h\right)}{\partial r_{dj}^{h}}+\left(\tilde{r}\left(1-\phi\right)-r_{dj}^{h}-c_{dj}^{h}\right)\frac{\partial^2 E\left(D_j^h\right)}{\partial r_{dj}^{h2}}}\right] < 0
\end{aligned}
$$

In all the derivatives in Equation (B.2), the denominators are negative due to the second-order condition for a maximum holding. Equation (3.13) implies that the numerator in the top row of Equation (B.2) is negative. Therefore, bank j's own deposit rate decreases in the number of branches it operates. By the law of supply, the numerator in the second row is positive — therefore, the optimal deposit rate increases in the interbank rate. By the same reasoning, the numerator in the third row of Equation (B.2) is negative — implying that the optimal deposit rate decreases in the marginal cost of retail lending. Equation(3.13) implies that the numerator in the fourth row of Equation (B.2) is positive — therefore, larger branch network size of competitors causes bank j to increase its optimal choice of the retail deposit rate. Finally, the numerator in the bottom row of Equation (B.2) is negative, implying that an increase in per capita income causes bank j to lower its optimal retail deposit rate.

B.2 Data Appendix

This section gives a detailed description of the data used in the estimation of the model.

Interest Rates. Bank–level data on interest rates come from the PSzÁF regulatory database. Interest rates are measured by the Effective Annual Percentage Rate (APR) for loans, and Effective Annual Percentage Yield (APY) for deposits. These measures are calculated on an annual basis, and also account for fees.

Bank Branch Network Size. Bank–level data come from the PSzÁF regulatory database. Data on the total number of bank branches in Hungary comes from the online database of Magyar Nemzeti Bank (2004-2007). Data on competitors' branch network size are calculated using both these sources.

Interbank Rates and Reserve Requirements. Data come from the MNB.

Currency Volatilities and Appreciation. Volatilities of the Hungarian Forint, the Swiss Franc and the Euro are measured as the standard deviation of the exchange rate between these currencies and the U.S. Dollar over the six months preceding the period. Exchange rate data come from the MNB.

Per Capita Income. Data come from the Hungarian KSH's online database.

Bank Discount Factor and Proportional Costs. Bank–specific discount factors are calculated from data on lending rates. The average discount factor over the sample period is 0.924. Branch operational cost $(c_n)_t$ is the ϱ_{3t} term from the Total Variable Cost equation in (3.32). All other proportional costs are also coefficients from (3.32).

Table B.1: Summary Statistics.

Name	Min	25p	50p	75p	Max	Mean	S.D.
HUF Loan Rate	8.46	19.30	23.06	27.82	35.40	23.55	5.18
EUR Loan Rate	2.58	9.02	12.62	15.23	21.06	12.26	4.08
CHF Loan Rate	3.91	7.48	10.21	12.73	18.49	10.52	3.40
HUF Mort. Rate	4.75	10.55	12.21	14.54	27.82	12.64	3.31
EUR Mort. Rate	0.79	5.70	6.87	7.70	11.24	6.74	1.70
CHF Mort. Rate	1.57	4.62	5.32	6.08	8.07	5.34	1.12
HUF Firm Rate	6.82	8.36	9.23	11.68	13.74	9.90	1.98
EUR Firm Rate	2.20	3.40	3.94	4.68	5.73	4.03	0.87
HUF Dep. Rate	3.22	5.84	6.90	8.51	11.78	7.39	2.02
EUR Dep. Rate	0.01	1.27	1.97	2.75	10.02	2.24	1.97
HUF Volatility	1.12	2.11	2.76	3.94	5.15	3.03	1.09
EUR Volatility	0.75	1.59	2.17	3.22	5.21	2.44	1.02
CHF Volatility	0.96	1.39	1.86	3.00	4.56	2.31	1.03
HUF Appreciation	0.96	0.98	1.01	1.03	1.05	1.01	0.03
EUR Appreciation	0.96	0.99	1.00	1.02	1.04	1.01	0.02
CHF Appreciation	0.96	0.99	1.00	1.02	1.06	1.00	0.02

Table B.1: (Continued)

Name	Min	25p	50p	75p	Max	Mean	S.D.
MC of Retail Loans	19.61	21.03	22.41	23.20	24.00	21.99	1.25
MC of Mortgages	8.17	8.76	9.34	9.67	10	9.16	0.52
MC of Deposits	1.63	1.75	1.86	1.93	2.00	1.83	0.10
Own Branch (100's)	0.32	0.68	1.53	1.82	4.33	1.72	1.30
Competitors' Branches (100's)	7.06	10.57	11.26	12.96	14.66	11.42	18.84
Per capita Income	0.06	0.06	0.06	0.06	0.07	0.06	0.01
Branch Oper. Cost	12.76	17.50	19.54	21.24	32.37	19.51	3.53
Branch Expansion	−6	0	1	1	6	0.67	1.74

Table B.2: Summary of Interest Rates by Time Period.

Time	HUF Loan	EUR Loan	CHF Loan	HUF Firm	EUR Firm	HUF Mor	EUR Mor	CHF Mor	HUF Dep	EUR Dep
04/01	22.43	–	–	11.68	–	13.90	–	–	9.03	–
04/02	24.64	–	–	12.91	–	15.76	–	–	10.01	–
04/03	25.39	–	–	13.68	–	19.81	–	–	11.07	–
04/04	26.85	–	–	13.74	–	17.45	–	–	10.61	–
04/05	26.12	–	–	12.84	–	15.83	–	–	10.09	–
04/06	26.45	–	–	13.45	–	16.82	–	–	10.50	–

Table B.2: (Continued)

Time	HUF Loan	EUR Loan	CHF Loan	HUF Firm	EUR Firm	HUF Mor	EUR Mor	CHF Mor	HUF Dep	EUR Dep
04/07	26.73	–	–	13.48	–	16.39	–	–	10.56	–
04/08	27.32	–	–	13.63	–	16.62	–	–	10.86	–
04/09	27.61	–	–	13.15	–	14.24	–	–	9.90	–
04/10	26.86	–	–	12.45	–	14.23	–	–	9.35	–
04/11	26.89	–	–	12.44	–	14.53	–	–	9.25	–
04/12	29.21	–	–	12.07	–	14.05	–	–	9.21	–
05/01	26.15	10.54	9.37	10.86	2.85	13.40	6.58	5.66	8.12	0.61
05/02	24.74	11.23	10.19	10.67	3.15	13.10	6.35	5.39	7.67	0.93
05/03	24.16	13.91	10.21	9.77	2.87	12.67	6.53	5.48	7.22	2.51
05/04	22.61	10.85	10.23	9.23	2.80	12.05	8.46	5.16	6.37	0.67
05/05	22.68	10.08	11.44	9.13	2.98	13.18	6.53	4.85	6.53	0.90
05/06	23.00	12.18	10.62	9.2	3.31	13.26	6.64	5.51	6.43	1.14
05/07	20.39	10.93	11.11	9.2	3.57	15.38	6.97	5.82	6.13	1.56
05/08	20.88	13.12	10.62	9.26	4.00	14.50	7.53	6.18	6.44	1.88
05/09	23.93	11.46	10.30	8.27	3.40	12.64	7.04	5.65	5.47	2.29
05/10	21.36	11.55	10.13	8.32	3.76	12.09	7.19	6.28	5.18	1.46
05/11	22.73	11.91	9.7	8.09	3.51	10.81	5.95	5.77	6.22	1.35
05/12	22.63	10.67	10.14	8.23	3.90	10.83	6.57	5.88	5.70	1.72
06/01	21.92	11.42	10.20	8.08	3.82	10.96	7.27	5.77	5.56	1.68
06/02	23.10	11.53	10.82	7.95	3.74	10.86	7.42	5.66	5.42	1.53
06/03	22.58	13.21	10.97	7.55	3.50	11.05	7.06	5.31	5.08	1.20

Table B.2: (Continued)

Time	HUF Loan	EUR Loan	CHF Loan	HUF Firm	EUR Firm	HUF Mor	EUR Mor	CHF Mor	HUF Dep	EUR Dep
06/04	24.03	9.58	10.97	7.44	3.46	9.78	6.21	5.09	4.93	1.23
06/05	22.70	10.88	10.25	7.19	3.19	9.26	5.38	4.83	4.81	0.92
06/06	22.41	11.99	11.30	7.98	4.10	10.82	6.40	5.56	5.35	1.86
06/07	22.88	14.44	10.97	8.36	4.33	10.94	8.01	4.88	6.37	2.15
06/08	22.61	11.51	11.58	8.85	4.59	11.28	8.30	5.46	6.72	2.88
06/09	20.64	11.60	9.01	6.82	2.20	9.41	4.67	3.23	4.48	0.28
06/10	21.47	13.06	10.87	9.24	4.23	11.80	7.24	5.31	6.93	2.32
06/11	22.75	12.28	10.25	9.66	4.68	12.02	7.30	5.54	7.64	2.75
06/12	23.97	12.13	11.00	9.81	5.06	11.88	6.85	5.74	8.27	2.87
07/01	22.48	12.4	10.30	8.71	3.94	11.34	6.02	4.65	6.90	1.89
07/02	23.08	12.01	10.29	8.74	3.99	11.29	6.41	4.57	6.90	1.99
07/03	22.74	13.63	10.35	9.15	4.58	11.44	7.23	4.76	7.37	2.39
07/04	23.42	14.41	10.97	9.42	4.86	11.61	6.60	5.32	7.38	2.72
07/05	21.89	11.83	10.49	9.08	4.61	11.34	6.29	4.92	6.55	2.57
07/06	22.93	13.21	10.85	9.45	5.17	11.66	6.94	5.41	7.42	3.14
07/07	21.65	13.76	11.21	9.69	5.58	11.59	5.99	6.01	7.34	3.45
07/08	23.32	14.63	11.69	9.76	5.73	11.03	6.60	5.95	7.55	3.83
07/09	22.46	15.30	10.51	8.95	5.20	11.01	6.58	5.36	6.74	3.20
07/10	17.47	8.34	8.56	8.78	5.06	9.16	6.47	4.75	6.43	6.67
07/11	22.34	12.54	9.96	8.97	5.23	9.52	6.11	5.06	6.95	4.74

Table B.3: Averages of Branch Network Sizes (A) and Branch Network Expansion Choices (B).

Yr 04	A	B	Yr 05	A	B	Yr 06	A	B	Yr 07	A	B
J	148.8	0	J	166	0.60	J	172.4	0.40	J	185	0.80
F	148.8	0.20	F	166.6	0.20	F	172.8	0	F	185.8	0.40
M	149	0.20	M	166.8	−0.40	M	172.8	1.40	M	186.2	0.60
A	149.2	−0.20	A	166.4	−0.20	A	174.2	1.20	A	186.8	0
M	149	0.20	M	166.2	−0.40	M	175.2	1.20	M	186.8	0.60
J	149.2	1.60	J	165.8	0.40	J	176.6	1.20	J	187.4	0.80
J	154.2	1.60	J	166.2	0.80	J	177.8	1.40	J	188.2	0.20
A	159	1.60	A	167	0.40	A	179.2	1.20	A	188.4	0.80
S	164	0.80	S	167.4	1.80	S	180.4	1.40	S	189.2	0.80
O	164.8	0.20	O	169.2	1.40	O	181.8	1.40	O	190.4	0.40
N	165	0.80	N	170.6	1.80	N	183.2	1.40	N	190.4	0
D	165.8	0.20	D	172.4	0	D	184.6	0.40			

Table B.4: Summary of Model Variables and Empirical Measures.

Variable Name	Note	Empirical Measure
Retail Loan Rate	r_l^h	Monthly Bank Rate
Retail Deposit Rate	r_d^h	Monthly Bank Rate
Firm Loan Rate	r_l^c	Monthly Market-Average Rate
Own Branch Network	n_j	Monthly Bank Network Size
Hhold's Discount Factor	β^h	N/A

Table B.4: (Continued)

Variable Name	Note	Empirical Measure
Firm's Discount Factor	β^c	N/A
Total Number of Branches	N	Monthly total Branch Network
Per-capita Income	I	Monthly Per-capita Income
Total Deposit Supply	D^h	Monthly Aggregate Sum
Total Retail Loan Demand	L^h	Monthly Aggregate Sum
Total Firm Loan Demand	L^c	Monthly Aggregate Sum
Retail per-capita Savings	s^h	N/A
Retail per-capita Loan & Firm Loan	$\left(l^h; l^c\right)$	N/A
Retail per-capita Deposits	d^h	N/A
Total Number of Firms	F	N/A
Required Reserve Ratio	ϕ	Monthly RRR from MNB
Interbank Rate	$\tilde{r}$	Monthly Interbank Rate
Hhold Distance to branch	x	N/A
Per-capita Lifetime Consumption	C	N/A
Firm's Capital Input	k	N/A
Proportional Costs	$\left(c_l^h; c_d^h\right)$	Estimated from TVC equation
	$\left(c_n; c_l^c\right)$	
Entry Costs & Scrap Value	$(f; e)$	Estimated from Model
Branch Network Expansion	a_j	Change in Network Size
State & Structural Variables	$(\Theta; \Xi)$	N/A
Firm's Variable & Total Profit	$(\pi; \Pi)$	Functional Forms as in Model
Firm Output & Equity	(y, b)	N/A
Private Shock	ϵ_j	Draws from Std. Normal Dist.

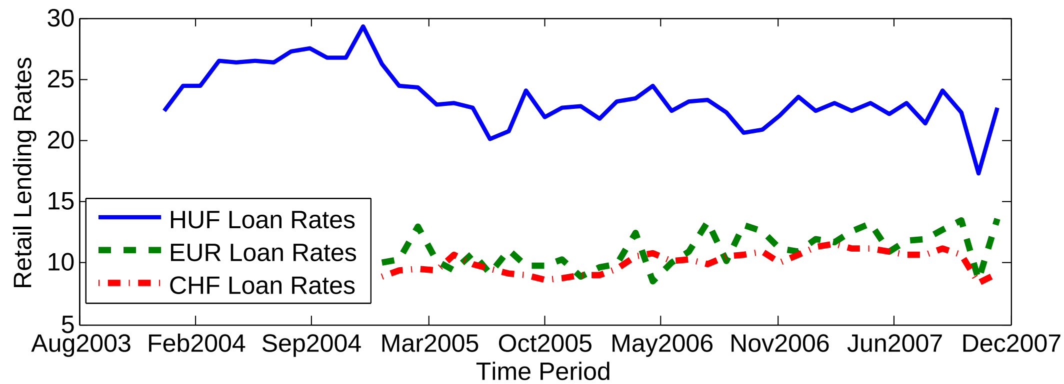

Figure B.1: Lending Rates Adjusted for Currency Appreciation and Inflation.

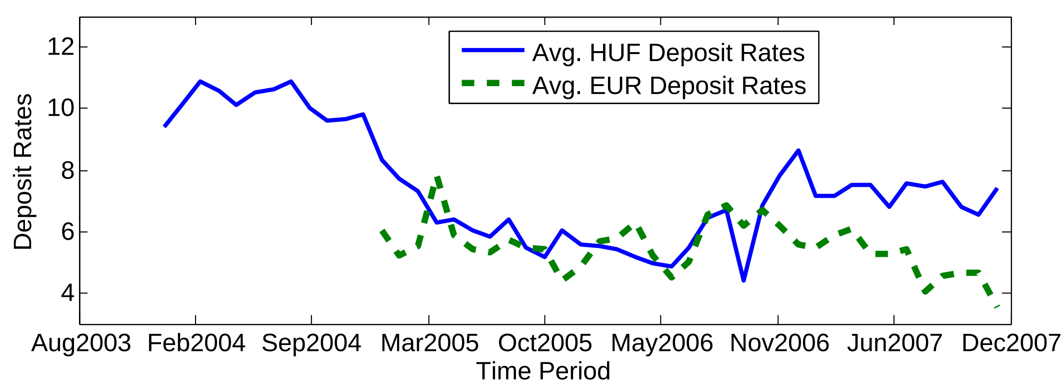

Figure B.2: Deposit Rates Adjusted for Currency Appreciation and Inflation.

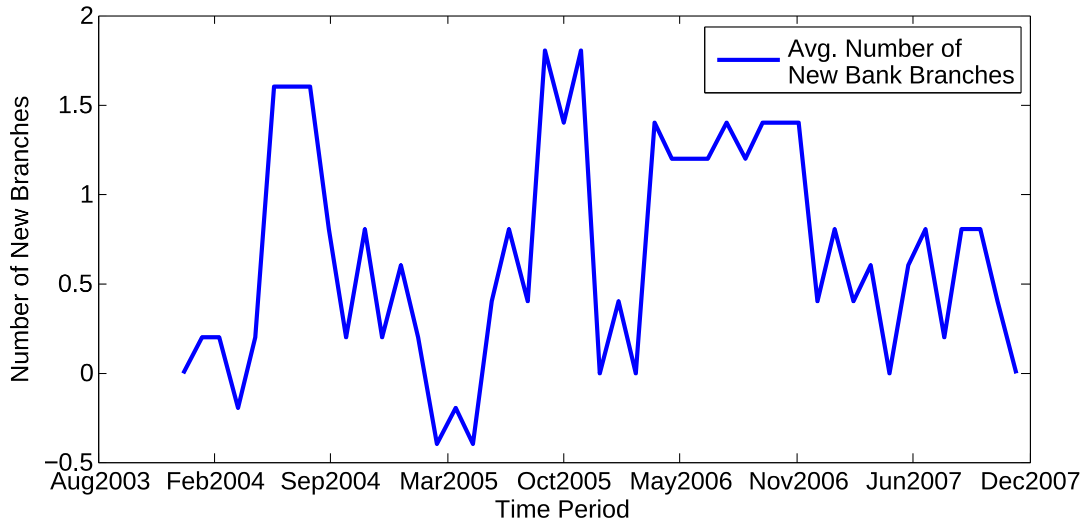

Figure B.3: Average Expansion of Branch Network Size Over Time.

B.3 Simulation Exercises

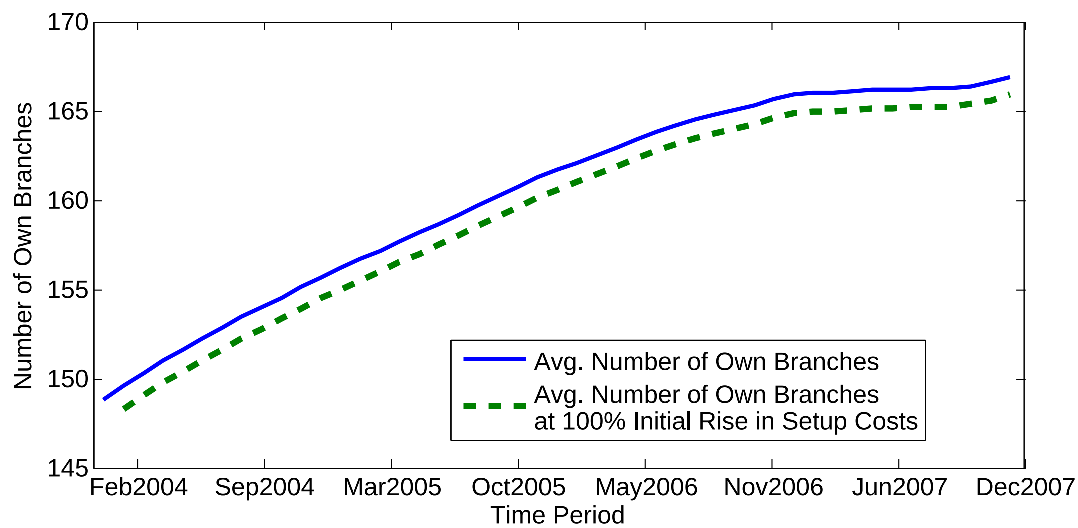

Figure B.4: Branch Network Size and Increases in Branch Setup Costs.

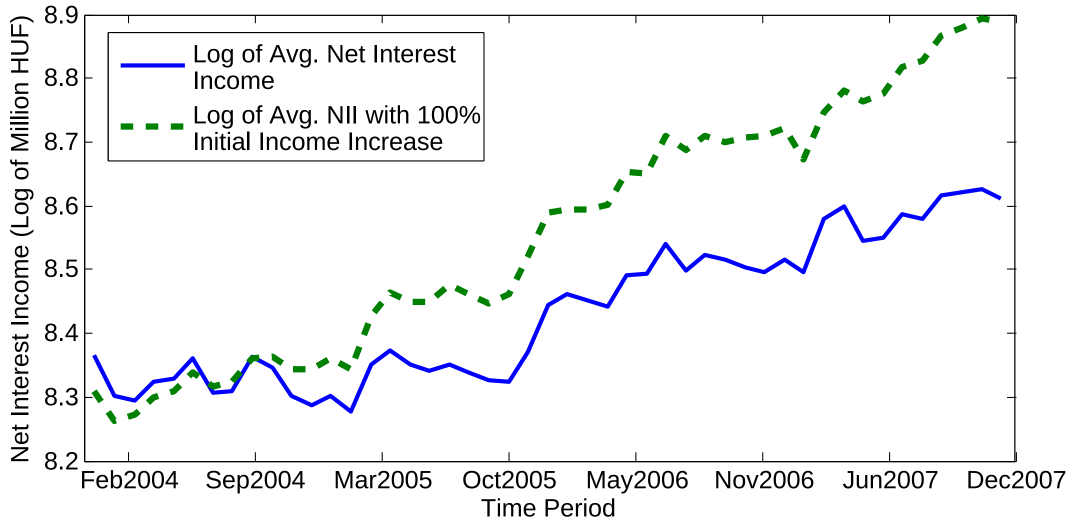

Figure B.5: Net Interest Income and Increases in Per Capita Consumer Income.

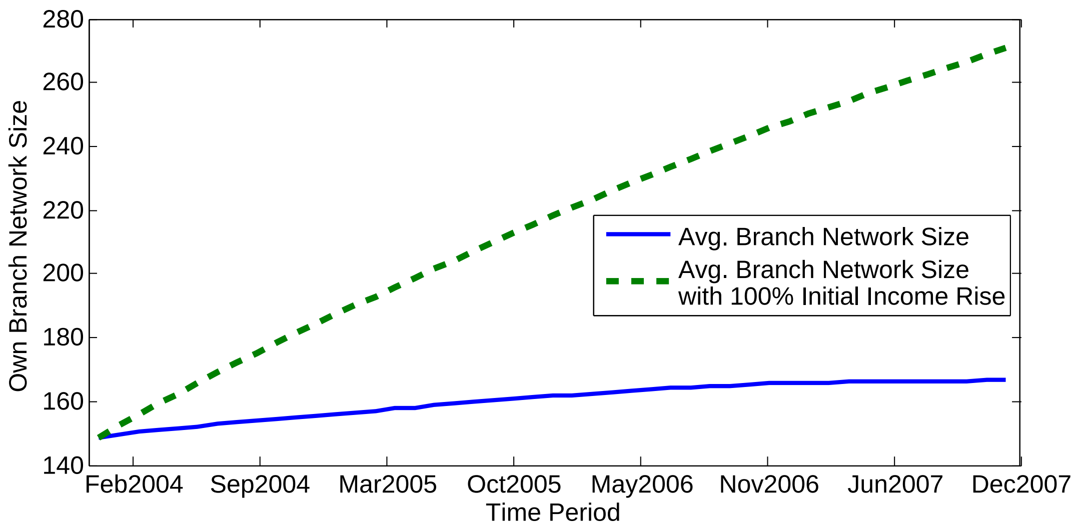

Figure B.6: Branch Network Size and Increases in Per Capita Consumer Income.

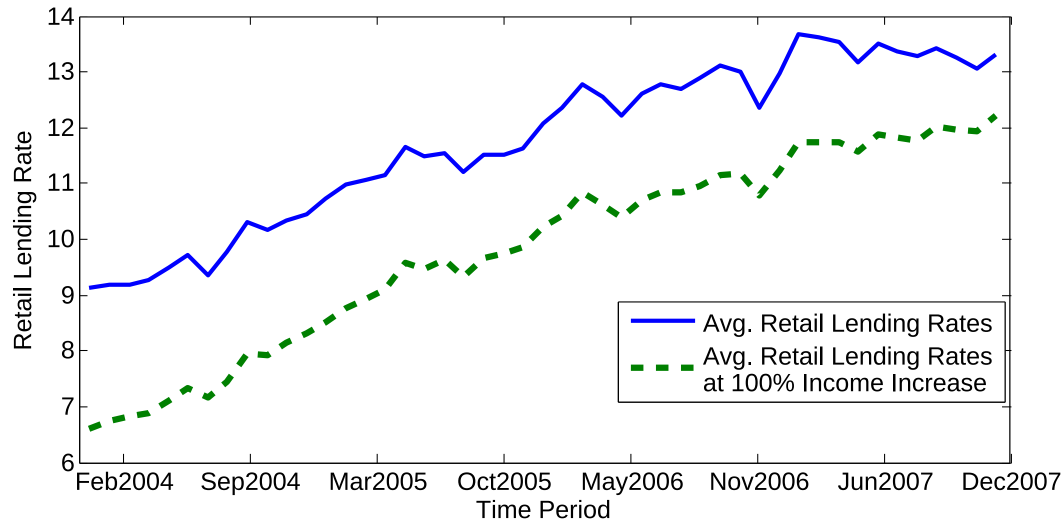

Figure B.7: Retail Lending Rates and Increases in Per Capita Consumer Income.

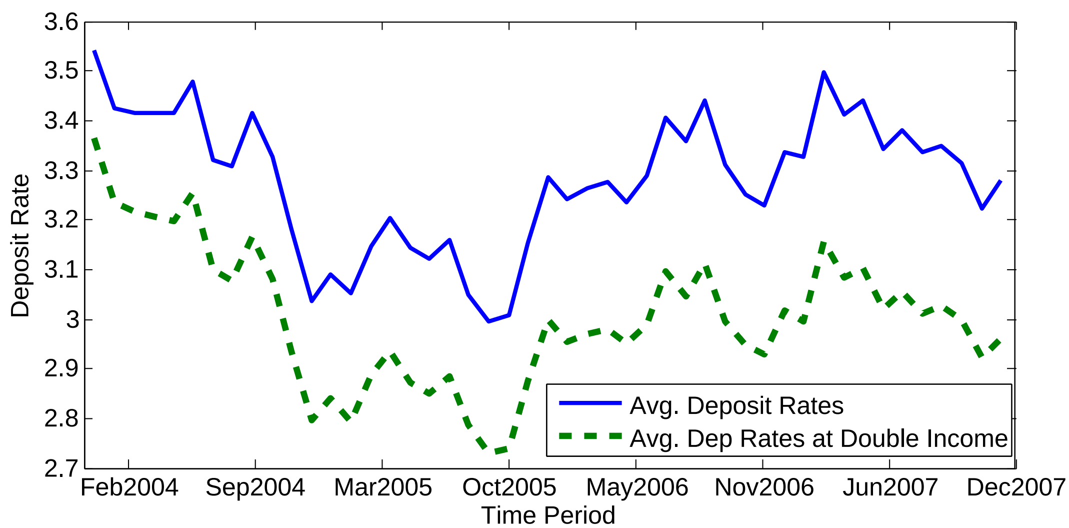

Figure B.8: Deposit Rates and Increases in Per Capita Consumer Income.

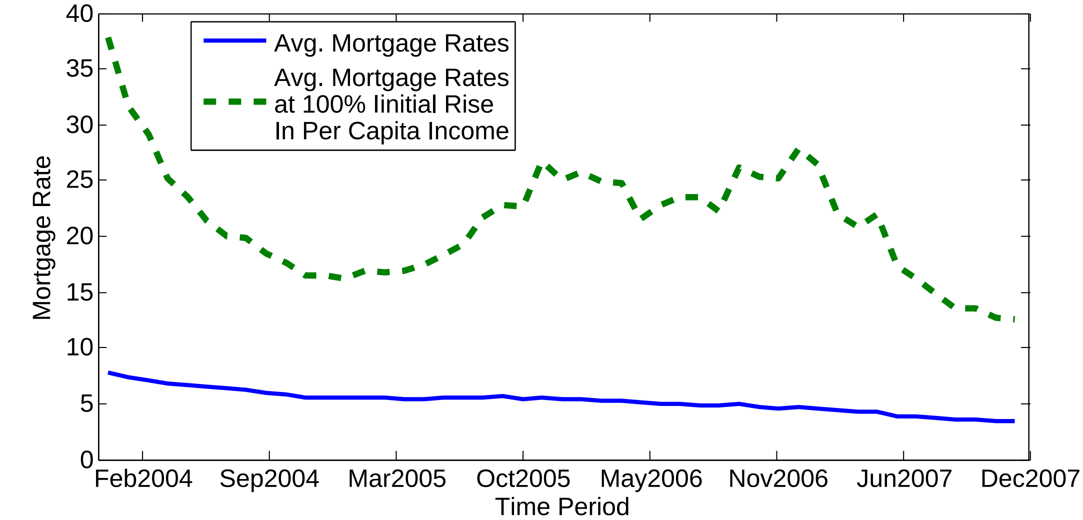

Figure B.9: Mortgage Rates and Increases in Per Capita Consumer Income.

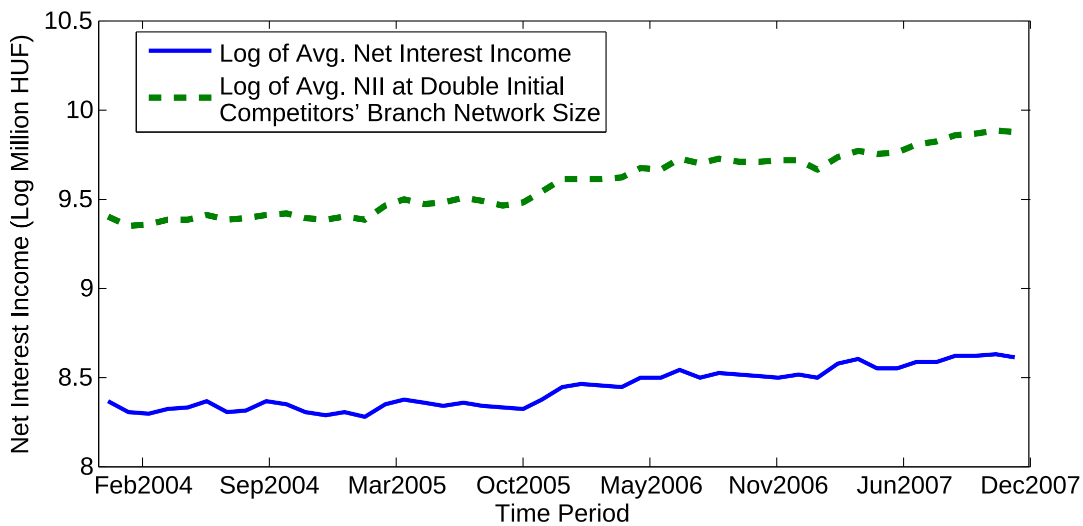

Figure B.10: Net Interest Income and Increases in Competitors’ Branch Network Size.

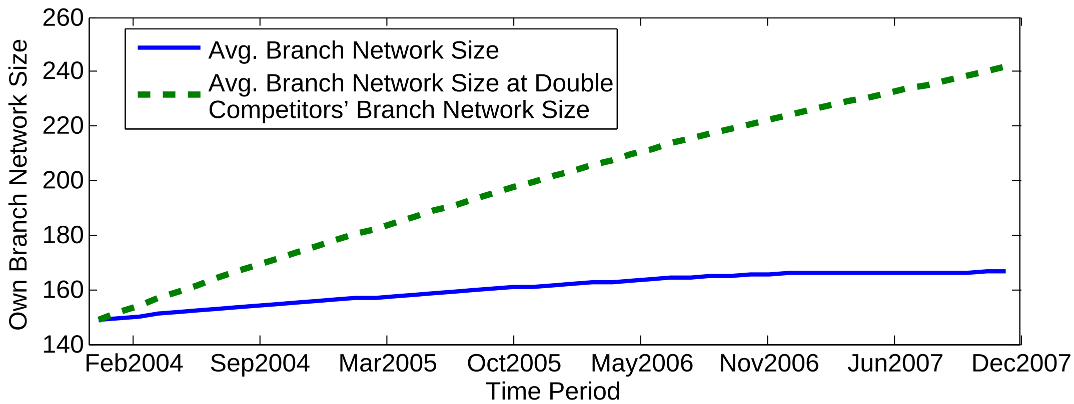

Figure B.11: Branch Network Size and Increases in Competitors' Branch Network Size.

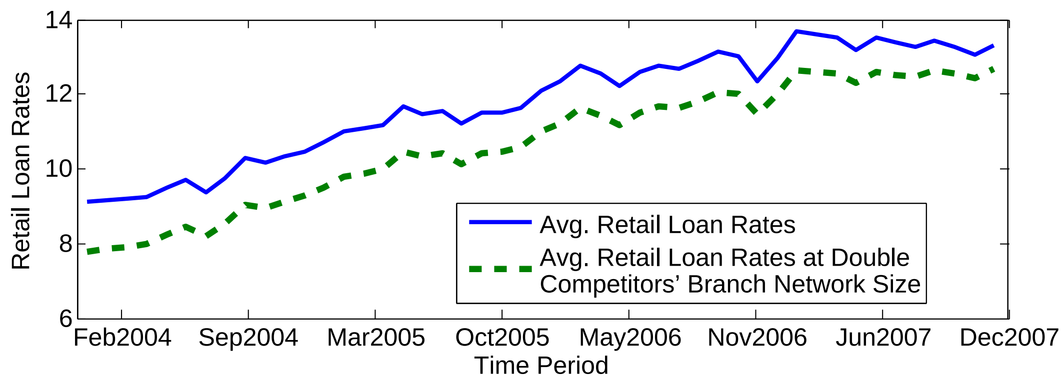

Figure B.12: Retail Lending Rates and Increases in Competitors' Branch Network Size.

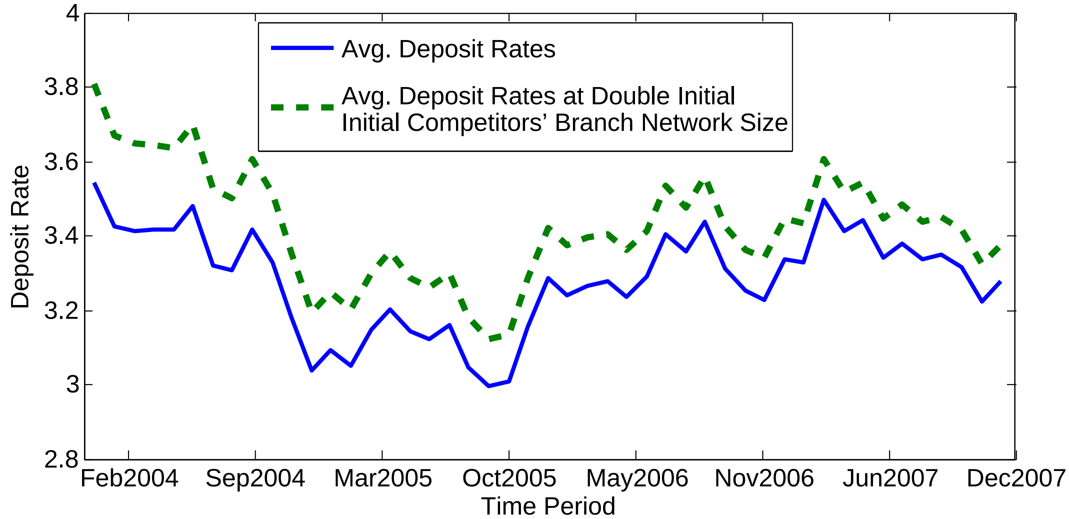

Figure B.13: Deposit Rates and Increases in Competitors' Branch Network Size.

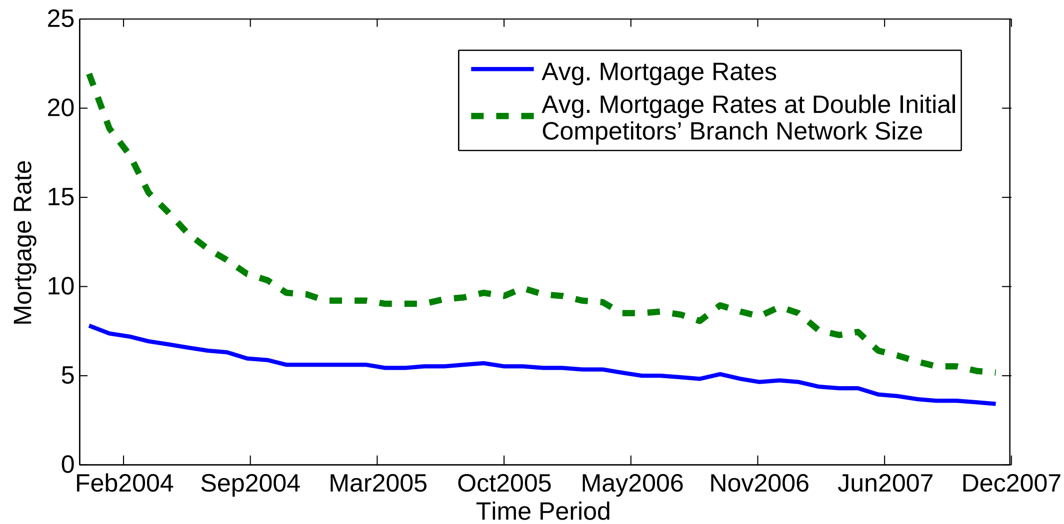

Figure B.14: Mortgage Rates and Increases in Competitors' Branch Network Size.

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